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ABSTRACT

This document contains project-oriented lessons and hands-on activities developed to integrate steel recycling, natural resource conservation, and solid waster management into science learning. It is designed to assist secondary teachers and students (grades 9-12) in meeting state and local goals for learning in biology, chemistry, general science and earth science, and physics. The first lesson, "Supply & Demand" includes the activities "Reducing Food Spoilage and Waste" and "Space Food." The activities included in the second lesson concerning "Collect & Haul" are "Leachate Collection" and "Composing with Worms." "Bones and Levers" and "The Color of Hot Metals" are the activities included with the third lesson concerning the topic "Sort & Produce." Also included is a cross-reference chart of activities to biology concepts and critical thinking skills, glossary, student worksheets, a 17-item resource list, and a teacher evaluation form. Each lesson contains a short bibliography. (MKR)

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Cycles for Science

ED 393 653

Biology

Curriculum Supplement for Grades 9-12

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Foreword:
Steel Recycling Institute

The Steel Recycling Institute (SRI) is dedicated to promoting and sustaining steel recycling across the country. The SRI recognizes the value of incorporating recycling and solid waste management information into the educational process and encourages responsible solid waste handling. ***Cycles for Science*** provides teachers and students with a greater understanding of steel and steel can recycling and encourages responsible solid waste handling practices.

Steel is America's most recycled material. Steel cans and other steel products are recycled into a variety of new steel products. A steel can may become part of a car, a bridge or perhaps a child's toy. Since steel can be recycled infinitely, the cycle continues as steel products are again recycled. Steel cans are collected for recycling through a variety of programs, including curbside, drop-off, multi-material buyback, and commercial/institutional recycling. In some communities, steel cans and other household steel products are collected for recycling automatically through magnetic separation at resource recovery facilities.

Recycling helps the environment, conserves natural resources and saves energy. The Steel Recycling Institute is proud to help provide opportunities for solid waste management education. While this program focuses on steel and steel can recycling, the SRI supports the recycling of all recyclable materials and promotes integrated solid waste management practices. Students who learn about recycling today will be well prepared for the resource management of tomorrow.

Bill

William M. Heenan, Jr.
President

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About Cycles for Science

Welcome to the *Cycles for Science* program designed by the Steel Recycling Institute to assist secondary teachers and students (grades 9 - 12) in meeting state and local goals for learning in biology, chemistry, general science and earth science, and physics. Curriculum supplements in each of these core areas of science contain project-oriented lessons and hands-on activities. Also available is a curriculum supplement for community volunteer projects, appropriate for student groups and community organizations.

The motivation for creating *Cycles for Science* was requests from secondary teachers for activities which bring real-life science into the classroom. The goal of this program is to integrate steel recycling, natural resource conservation and solid waste management into science learning.

Cycles for Science was developed in cooperation with secondary teachers and solid waste management professionals and is part of the Steel Cycles program for kindergarten through grade 12.

The Steel Recycling Institute

The Steel Recycling Institute (SRI) assists community leaders, recyclers, business people, and educators in developing steel recycling programs and raising public awareness. Located in Pittsburgh, Pennsylvania, the SRI has established a network of regional offices to help communities conduct steel recycling activity within existing programs. To supplement recycling activity and encourage long-term commitment to responsible solid waste management practices, the SRI is working toward the development of comprehensive educational programs.

Lessons at a Glance

Cycles for Science Biology is designed to assist secondary teachers in meeting state and local goals for learning in biology. This "user-friendly" curriculum supplement consists of three lessons, each containing two activities with a common background that provides in-depth information not usually found in a high school textbook. The lessons are complete with teacher and student sections that are ready to copy, and with graphics which may be copied onto transparencies or used as handouts. Activities may be easily implemented using materials and equipment commonly found in a science lab or local retail store. The Steel Recycling Institute supports the philosophy of "reduce, reuse and recycle," and encourages teachers to make double-sided copies, use scrap materials when the activity calls for items such as newspaper and cardboard, and recycle waste materials whenever possible.

Cycles for Science activities furnish teachers with an approach to science reform, with real-life issues integrated into one or more sciences and across subject and skill areas. Teachers are encouraged to go beyond the lessons and activities by providing students with structured opportunities to get involved in school and community waste reduction and recycling programs. Such opportunities are suggested at the end of each lesson under the titles "Extension" and "Independent Study." In addition to classroom instructional use, the lessons and activities are ideal for student science projects and individual research.

Several *Cycles for Science Biology* activities contain suggestions for further study to reinforce concepts and laboratory skills. These suggestions may be found at the end of the *Procedure* in the *Activity: Teacher* sections. For information on techniques suggested in "For Further Study," refer to Morholt and Brandwein, *A Sourcebook for the Biological Sciences*, listed in the *Appendix: Bibliography*, page 54.

The Steel Recycling Institute (SRI) offers innovative teacher training workshops that feature activities from the *Cycles for Science* series. For more information, contact the SRI at 412/922-2772.

Objectives at a Glance

Each lesson begins with a statement of the objectives for the activities in that lesson. The objectives reflect trends in science reform and are constructed from these components:

Performance objectives

The skills the learner will develop and internalize as a result of a coherent, successful science education; a benchmark of achievement.

Instructional objectives

The immediate objectives of the activity, derived from four elements of quality science education:

Scientific inquiry: The manner in which science is done; processing skills, abilities, habits of mind, and attitudes towards scientific exploration and understanding of the natural world.

Scientific knowledge: The scientific concepts under study; principles, laws, theories, ideas and information to be learned.

Conditions for learning science : The strategies, activities and settings utilized to engage critical thinking skills and support the learning of science.

Applications for science learning: The connection with real-life situations; the opportunity for learners to use their store of scientific skills and knowledge in meaningful and innovative ways.

Lesson: Supply & Demand

Pages 1-18

Objectives

Performance objectives: In this lesson, students will construct and test models of a food canning process and a food serving system for space travel in order to understand how processing and packaging can help meet the demand for safe, nutritious food.

	Activity 1. ***Reducing Food Spoilage and Waste***	*Activity 2.* ***Space Food***
	The learner will relate the impact of canning food to issues of food spoilage and waste, by:	Presented with information on food processing and packaging technologies, the learner will participate in designing, analyzing, and recommending improvements to a system for serving food in space, by:
Instructional objectives:		
Scientific inquiry	• conducting an investigation utilizing various canning treatments to reduce food spoilage	• analyzing the effect of two variables — gravity and limitations in physical space — on a food serving system
Scientific knowledge	• formulating explanations for the influence of food spoilage organisms on the shelf life of food	• formulating plans that can be used to accommodate the conditions for eating in space
Conditions for learning science	• collecting and analyzing observations on food spoilage over time, and comparing observations to commercial canning procedures	• developing possible courses of action in response to the risks of food spoilage and waste
Applications for science learning	• preparing a persuasive presentation on the impact of food spoilage on the environment, based on scientific principles and research	• designing and constructing a food serving system for extending the ease and comfort of eating in space

The activities in this biology lesson may be integrated with other subject areas:

Reducing Food Spoilage and Waste: chemistry, home economics, math, social studies

Space Food: earth science, industrial arts, physics, social studies

Lesson: Collect & Haul

Pages 19-34

Objectives

Performance objectives: In this lesson, students will develop a better understanding of solid waste management by long term collection of leachate from decaying organic matter, and construction and maintenance of a worm box for composting organic matter as an alternative to hauling it to a landfill.

Instructional objectives:

	Activity 3. Leachate Collection	*Activity 4.* Composting with Worms
	The learner will develop an evidence based position regarding the issue of leachates from landfills, by:	The learner will gather data and develop a position on the issue of solid waste management, by:
Scientific inquiry	• constructing and testing models of leachate collection systems, with soil type and organic waste as variables	• constructing a worm composting box and comparing it over time to a control box
Scientific knowledge	• formulating hypotheses to explain differences in leachate production	• formulating hypotheses to explain the components that lead to growth or lack of growth of worms in the box
Conditions for learning science	• collaborating with other class members to perform an investigation over an extended period of time	• describing possible courses of action in response to issues of solid waste management
Applications for science learning	• showing how effective leachate management practices may reduce the risk from leachate runoff into groundwater	• writing environmental impact statements about worm composting boxes and municipal solid waste

The activities in this biology lesson may be integrated with other subject areas:

Leachate Collection: chemistry, social studies

Composting with Worms: mathematics, social studies

Lesson: Sort & Produce

Pages 35-52

Objectives

Performance objectives: In this lesson, students will examine the recycling process by classifying musculoskeletal levers and mechanical levers (such as those used in sorting commingled recyclables), and by relating the colors produced during steel-making to wavelength, temperature and anatomy of the human eye.

Instructional objectives:

	Activity 5. ***Bones and Levers***	*Activity 6.* ***The Color of Hot Metals***
	The learner will compare and contrast levers in the human body with levers in machinery, by:	The learner will conduct an investigation on the relationships between heat, wavelengths of visible light and color, by:
Scientific inquiry	• recognizing and utilizing lever classification systems for exploring musculoskeletal and mechanical levers	• utilizing the chart of wavelengths of visible light to predict temperatures of flames and explain color changes as metals are heated
Scientific knowledge	• formulating hypotheses to explain the interaction of components of levers	• formulating a description of the impact of electromagnetic waves on perception of color
Conditions for learning science	• refining the use of mathematical skills by applying these skills in a scientific investigation	• refining the use and understanding of the following concepts: mass, specific heat, and force
Applications for science learning	• investigating the working of tools that extend the limits of human capabilities	• comparing school based science perspectives with technological applications

The activities in this biology lesson may be integrated with other subject areas:

Bones and Levers: industrial arts, mathematics, physics

The Color of Hot Metals: industrial arts, mathematics, physics

Cross-Reference of Activities to Biology Concepts and Critical Thinking Skills

LESSON:	SUPPLY & DEMAND		COLLECT & HAUL		SORT & PRODUCE	
ACTIVITY:	1 Reducing Food Spoilage and Waste	2 Space Food	3 Leachate Collection	4 Composting with Worms	5 Bones and Levers	6 The Color of Hot Metals
BIOLOGY CONCEPTS						
Animal form and function						
human anatomy					•	•
macroinvertebrates				•		
microorganisms	•			•		
nutrition	•	•				
Chemistry of life						
decomposition			•	•		
Ecology						
solid waste	•	•	•	•		
CRITICAL THINKING SKILLS						
problem solving		•				
creative thinking		•	•	•		
decision making	•	•	•	•	•	•
communication	•	•	•	•	•	•
collaboration	•	•	•	•	•	•
leadership	•	•	•	•	•	•
organization	•	•	•	•	•	•

The Steel Cycle and Cycles for Science: Linking the Process to Learning

Lesson: Supply & Demand

In this lesson, students will construct and test models of a food canning process and a food serving system for space travel, in order to understand how processing and packaging can help meet the demand for safe, nutritious food.

Objectives

Activity 1. Reducing Food Spoilage and Waste

The learner will relate the impact of canning food to issues of food spoilage and waste, by:

- conducting an investigation utilizing various canning treatments to reduce food spoilage
- formulating explanations for the influence of food spoilage organisms on shelf life of food
- collecting and analyzing observations on food spoilage over time and comparing observations to commercial canning procedures
- preparing a persuasive presentation on the impact of food spoilage on the environment, based on scientific principles and research

Activity 2. Space Food

Presented with information on food processing and packaging technologies, the learner will participate in designing, analyzing and recommending improvements to a system for serving food in space, by:

- analyzing the effect of two variables — gravity and limitations in physical space — on a food serving system
- formulating plans that can be used to accommodate the conditions for eating in space
- developing possible courses of action in response to the risks of food spoilage and waste
- designing and constructing a food serving system for extending the ease and comfort of eating in space

Key Terms

Key terms are highlighted in the *Background: Student* with definitions provided in the *Glossary*.

brine
food processing
shelf life
thermal processing
municipal solid waste

Motivation

Contact your local library to obtain a video of the Apollo moon landing. Show the video to the class and encourage students to speculate on how food is served to an astronaut during a space mission. Ask them to compare their ideas to how meals are served at home and at school, and to predict if the same type of packaging used for foods at home or school might be used on a space mission.

Show students an empty coffee can and ask them to predict how many meals it would take to fill the can with food waste. Ask them to test their hypotheses at home. Instruct them to prepare a statement about food waste during space travel. (Students should realize that food waste is an important issue and should be minimized in space as well as on Earth).

Demonstration

Instruct students to keep a record of the foods and beverages they consume each day for a week. Collect samples of the five foods and beverages consumed most often by students in the class and test the foods for nutritional content (carbohydrate, fat and vitamin C). Include at least one fresh-squeezed citrus juice for the demonstration. Before the tests, ask students to predict the nutritional content of each food. After the tests, discuss the nutritional value of the food samples.

- Starch (a carbohydrate). Put three drops of iodine on a potato (control). Place three drops on each food sample and compare them to the control. Iodine stains starch granules blue.

Caution: Iodine stains skin and clothing and is dangerous if taken orally or absorbed through the skin.

- Fat. Rub margarine on a brown piece of paper and allow it to dry. Hold the paper toward the light and record observations. Repeat the procedure by rubbing the food samples on the brown paper.
- Vitamin C. Test the beverages for vitamin C content using indophenol, a blue liquid that turns colorless when vitamin C is present. Measure 5 mL of indophenol into a test tube and set it aside as the control. Measure 5 mL of indophenol into a second test tube. Select a beverage and add one drop at a time to the indophenol in the test tube. Record the number of drops it takes to turn the solution colorless. If after 20 drops the indophenol is still blue, mark the sample >20. The higher the vitamin C content of the beverage, the fewer drops it will require to turn the indophenol colorless.

Compare the class eating habits with the U.S. Department of Agriculture Food Guide Pyramid. Does the class as a whole have a balanced, nutritious diet? If not, what improvements could be made?

Content Development

Copy onto transparencies or use as handouts *Characterization of the Municipal Solid Waste Stream by Material* and *Packaging Recycling Rates for the United States*, pages 3 and 4. Copy and distribute to each student the *Background: Student*, pages 5 and 6. Use the figures and background reading as references to discuss food processing and packaging as an effective means of supplying nutritious food. For additional information on nutrition and health, refer to a biology text. For more information and activities on municipal solid waste, see *Lesson: Collect & Haul*.

Extension

The following activity expands on concepts introduced in this lesson.

Food Packaging Diary

Ask students to collect all food and beverage packaging they use in a week and separate it by type (e.g., steel cans, cardboard, aluminum, plastic, glass; milk and juice cartons may be classified as paper.) If storage space is available, students may bring the packaging to the classroom; otherwise they may store it at home. At the end of the week, mass the different types of packaging used by the class and calculate the percentage of each material. Compare the class percentages with the EPA percentages listed below the pie chart in *Characterization of the Municipal Solid Waste Stream by Material*, page 3. Discuss any differences between the class and EPA data (e.g., wood pallets are a type of packaging not likely to appear in the class data.)

Ask students to investigate which items of packaging collected are recycled locally and arrange for these items to be picked up or taken to a drop-off center. Discuss choices of foods and packaging that maximize nutrition and minimize waste.

Instruct students to develop a statement about the effect of packaging on their eating habits.

Independent Study

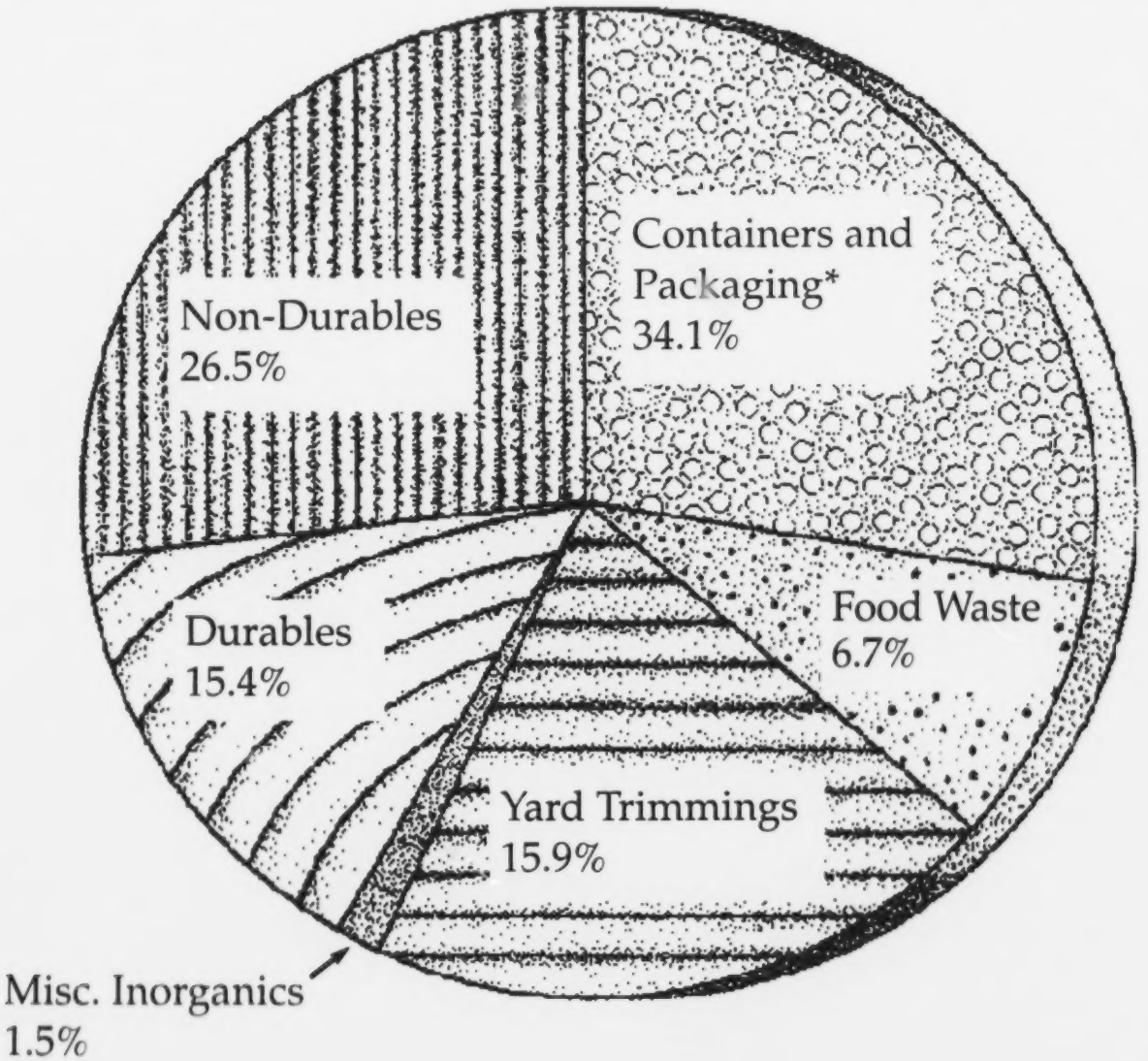
- Interview a grocery store manager to discuss consumer buying habits for fresh and processed foods. Inquire about trends, and how decisions are made as to which items and brands to stock.
- Write to NASA (see *Appendix: Resources*, page 57) for more information on space foods. Conduct a survey at a grocery store to determine which types of space foods are available locally.

Evaluation "Test Your Knowledge"

Evaluate learner understanding of the concepts introduced in this lesson. "Test Your Knowledge" suggestions:

- Create a flow chart for the steps in processing and canning carrots. Indicate the steps that prevent food spoilage. (Refer to *Carrot Canning Line*, page 10.)
- List the types of foods eaten at each meal during a "typical" day in space. Explain how each type of food is prepared and packaged. (Refer to *Types of Space Foods*, page 15.)
- Write an article for the school newspaper outlining the current issues in the food processing industry.

Characterization of the Municipal Solid Waste Stream by Material



*** Containers and packaging municipal solid waste was 50.1% paper, 17.3% glass, 13.5% wood, 11.9% plastic, 4.2% steel, 2.8% aluminum and <1% other.**

Source: U.S. EPA, *Characterization of Municipal Solid Waste in the United States: 1994 Update.* (1993 data. Percentages do not add up to 100 due to rounding.)

Packaging Recycling Rates for the United States

Type of Packaging*	Recycling Rate**	
	Million Metric Tons	Percent
Aluminum cans	0.914	63.1
Paper (corrugated cardboard)	15.118	62.0
Steel cans	1.180	48.0
Glass bottles	2.722	35.0
Plastic bottles	0.386	>16.0
Wood pallets	3.630	5.0

* Aseptic packages (e.g., drink boxes, milk cartons) are also recycled, but because the industry for recycling these items is relatively new, data was not available.

** Data courtesy of Chaz Miller, National Solid Waste Management Association, Washington, D.C. *Sources:* Aluminum Association, Can Manufacturers Institute, Institute of Scrap Recycling Industries, Glass Packaging Institute, Steel Recycling Institute, American Plastics Council, American Forest and Paper Association, U.S. EPA. Wood pallets 1990 data; all others 1993 data.

Lesson: Supply & Demand

HAVE YOU EVER WONDERED? *How a wide variety of nutritious foods are supplied to an ever - growing world population?*

We are fortunate in the United States to pay a smaller portion of our weekly income for food than many other countries in the world (Foreign Agricultural Service, January 1993). This can be attributed to a number of factors. Intensive farming practices and support from universities and government agencies allow farmers to achieve high yields per acre. A highly developed network of roads allows easy transportation from production regions to population centers. Warm climates in the southern regions of the United States and Mexico make it possible to produce certain fruits and vegetables in the winter months. In addition, food packaging and refrigeration permit a consistent, safe supply of a variety of foods, and greatly reduce waste from spoilage. According to the magazine article "Packaging in the '90s" (*Garbage*, December/January 1993), the United States has a remarkably low spoilage rate of food, less than three percent of the food supply. Many parts of the world with less sophisticated packaging and distribution systems still have a serious problem with food safety, supply, and spoilage.

The Food Processing Industry

Food processing is a means of providing consumers with a wide range of foods that might not be available fresh. According to the National Food Processors Association, food processing is the largest manufacturing industry in America. It includes the canning, freezing and food drying industries. Current issues in the food processing industry include:

- Increasing use of recycled materials in packaging. Recycled steel is used in steel food cans, which contain about 25 percent recycled content. Recycled aluminum is highly used in making new aluminum cans. Glass jars and cereal boxes also have recycled content. Certain products, such as soft drinks and salad dressing, may now be purchased in plastic bottles made from recycled soft drink bottles.

- Management of waste from the processing line. Many food processors are pursuing various waste management options to divert waste from landfills and lower waste disposal costs. Composting is an option because much of the waste produced on the food processing line is organic, such as over-cooked or undercooked food or discarded vegetable peelings, pea pods or corn husks. Another source of waste from the processing line is damaged cans and other packaging. Recycling is a method currently being used or investigated for management of damaged packaging.

- Food safety. Always of concern to the food processing industry, the current focus includes a ban proposed by the Food and Drug Administration (FDA) on the import of lead-soldered cans (lead soldering is not used by U.S. manufacturers). In addition, the U.S. Department of Agriculture (USDA) is re-evaluating chemical residues in food and the use of chemicals by food growers. With advanced technology, chemicals can now be measured in parts per trillion, far surpassing any scientific abilities of the past. Many of the USDA standards were set when measurements were made in parts per million.

- Diet, nutrition and health. New labeling laws are in effect to make labels more "user-friendly" and to reflect new findings on nutrients (particularly fats) in the diet. Labeling of biotechnology foods (foods resulting from genetic engineering) is a topic of great debate. One of the unknowns about biotechnology foods is allergenicity (the capacity to induce an allergic reaction).

Food Packaging and Recycling

An integral part of food processing is food packaging. Processed foods (and many fresh foods such as meat) must be packaged to preserve and sell the food. Packaging comes in many shapes, sizes, and materials, and serves many needs. It contains the

product, protects it during transport and storage, provides information on product content, and makes the product convenient to use.

Often there is more than one layer of packaging. Cereal, for instance, may be packaged in a plastic bag, the primary package, which contains and protects the cereal. The plastic bag is tucked inside a paperboard box, the secondary package, which further protects the product, advertises the product, and may make handling by the consumer easier. Individual boxes of cereal generally are shipped together in a larger box, the third layer of packaging, which again serves to protect the product and makes it easier and less costly to transport. All three levels of packaging have a role in supplying the cereal to the consumer.

Once the food has reached its destination, however, something must be done with the packaging that is no longer needed. Although most packaging is still disposed of by landfilling or incineration, recycling has become an important way to reduce the amount of packaging in the **municipal solid waste** stream. Consumers can help reduce packaging waste by making a conscious effort to purchase products in packages that contain recycled content (such as the paperboard packaging mentioned previously) and can be recycled locally.

Canned Foods

Canning is a method of food processing in which the food is packaged in air-tight containers such as steel cans or glass jars. Canning involves several steps to ensure quality and safety and to increase the **shelf life** of the canned food. Since food spoilage is caused by enzymes produced naturally by the food or by microorganisms, many of the canning steps involve inactivating enzymes or eliminating microorganisms. For fruits and vegetables, the steps include:

- Grading, to sort and remove any visibly diseased fruit or vegetable.
- Washing, to remove microorganisms present on the surface of the fruit or vegetable (does not reach microorganisms in crevices or in the cells of the fruit or vegetable).
- Blanching, a short heat treatment that inactivates naturally occurring enzymes and kills some microorganisms.
- Peeling/trimming/quartering/slicing, to prepare the vegetable or fruit.
- Filling, with the vegetable or fruit, and a brine solution, acidic solution or syrup. Brine is a seven to ten percent salt solution that reduces bacterial spore resistance to thermal processing. Acidic solutions such as lemon juice inhibit the growth of food spoilage microorganisms. Syrup is added primarily for taste.
- Exhausting, a quick heat treatment that removes gases and air from the container.
- Sealing, to prevent entry of microorganisms into the can or jar.
- **Thermal processing**, a steam or boiling water treatment carried out for a specific length of time to kill all food spoilage microorganisms, including the spores, that remain in the can or jar after sealing.

Packaged Food in Space

Providing food for astronauts in space is a unique challenge. Improved technology in food science and packaging is required to provide astronauts with food that is appetizing, has a high level of nutrition, and can be prepared and eaten in the absence of gravity. Without adequate packaging, food spoilage in space could be a serious problem.

Packaged foods for space are researched and developed by food scientists, dietitians, and engineers at the NASA Food Systems Engineering Facility (FSEF) in Houston, Texas. Many of the foods used on shuttle missions can be found at grocery stores and specialty shops.

Activity 1: Reducing Food Spoilage and Waste

Objectives

The learner will relate the impact of canning food to issues of food spoilage and waste, by:

- conducting an investigation utilizing various canning treatments to reduce food spoilage
- formulating explanations for the influence of food spoilage organisms on the shelf life of food
- collecting and analyzing observations on food spoilage over time and comparing observations to commercial canning procedures
- preparing a persuasive presentation on the impact of food spoilage on the environment, based on scientific principles and research

Time

One class period to prepare the canned carrots

Two weeks for observation

Safety Tips

Encourage students to use caution when cutting carrots and to wear oven mitts when handling hot jars. Do not allow students to eat any of the carrots before, during or after the activity. Students should wear goggles for this activity.

Materials/Equipment

Balances

Beakers

Carrots (fresh)

Carrots (commercially prepared can)

Cutting boards

Distilled water

Hot plates

Jars (baby food or small canning jars, with lids)

Oven mits

Pan (two-liter sauce)

Petri dish (or similar container for holding carrot peels)

Scalpels or plastic knives

Sodium chloride (NaCl, table salt)

Tongs

Vegetable peeler

Figures/Tables

Causes of Food Spoilage, page 9

Carrot Canning Line, page 10

Procedure

1. Use the *Background: Student*, pages 5 and 6, to discuss food processing as a means of providing populations with nutritious diets, and as a contributing factor to the low food spoilage rate in the United States.

2. Copy onto transparencies or use as handouts *Causes of Food Spoilage* and *Carrot Canning Line*, pages 9 and 10. Refer to a standard biology or biochemistry text and review the concepts of enzymes and the classes of microorganisms. Use the *Background: Student* and the figures to describe how specific steps in the canning line inhibit the action of food spoilage enzymes and microorganisms.

3. Divide the class into lab groups. Provide each group with a balance, two 500-mL beakers, two fresh carrots of about the same size, a cutting board, 200 mLs of distilled water, a hot plate, four baby food or small canning jars with lids, a petri dish, ten grams of NaCl, a scalpel, a two-liter sauce pan, tongs and a vegetable peeler. The commercially prepared can of carrots will be used as an exhibit at the end of the experiment.

4. Students will need space in the classroom to store their canning jars during the two week observation period. Some organic waste will be generated from this activity (carrot peels and ends). Suggestion: Use the organic waste for worm food in *Activity 4: Composting with Worms*.

5. Copy and provide to each student *Activity 1: Student*, pages 11 and 12. Review the steps of the activity and highlight the following points:

- Before beginning make sure all equipment and utensils are clean, to avoid introducing microorganisms into the experiment. Instruct students to wash their hands.

- Glass jars are used in this activity so students can see the carrots once canned. The term "canning" refers to the process, regardless of whether steel cans or glass jars are used.

6. After two weeks, open a commercially prepared can of cut carrots (thermally processed) for students to compare with their "canned" carrots.

7. *For further study:*

- Cover carrot disks with lemon juice instead of water (do not add salt). Ask students to include the acid treatments in their observations.

- Observe microorganisms in spoiled carrots under the microscope. Use Gram staining techniques. Be careful not to touch or inhale any microorganism spores.

- Test the processed carrots for vitamin A.

Collecting and Analyzing Data

1. Assist students in calculating the percentage of organic waste (peels and ends) using the formula:

$$\frac{\text{total mass of peels and ends}}{\text{total mass of carrots}} \times 100$$

2. Arrange for students to observe the jars of carrots every few days. Ask them to record their observations in the chart "Food Spoilage and Waste," page 12, making special note of changes in the appearance. After two weeks, ask each group to compare its findings with those from other groups. Instruct each group to prepare a persuasive presentation on the environmental impact of food spoilage and waste, demonstrating understanding of the scientific principles learned from the background reading and student research.

Drawing Conclusions

Q1: *Which treatment(s) provided the most resistance to food spoilage? Why? Describe the role of canning in reducing food waste.*

A1: The jar in which the carrots in salt solution were thermally treated should have provided the most resistance to food spoilage. The salt solution reduces the resistance of spores to heat. The thermal treatment destroys microorganisms and spores. Canning reduces food waste by inactivating enzymes or eliminating microorganisms that cause food spoilage.

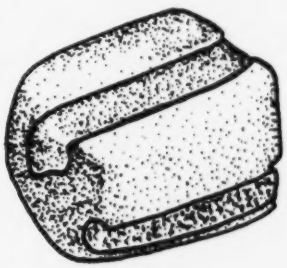
Q2: *What improvements in food production or technology would further reduce the amount of food spoilage and waste created each day? Consider both organic and packaging waste.*

A2: Students should propose methods that reduce food waste during processing, allow for composting or other use of unavoidable waste (peels and ends), extend the shelf life of processed food, and use packaging that conserves resources through reduction (e.g., lightweight packaging), reuse (e.g., refillable containers) or recycling (e.g., steel cans).

Causes of Food Spoilage

Enzymes

Occur naturally in fresh foods, and catalyze normal fruit ripening and decomposition. May also be produced by the microorganisms listed below.



Microorganisms

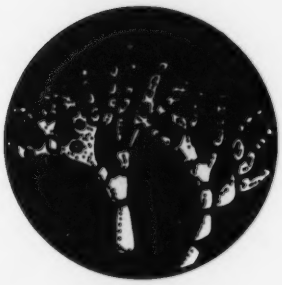
Bacteria

Bacilli

Cocci

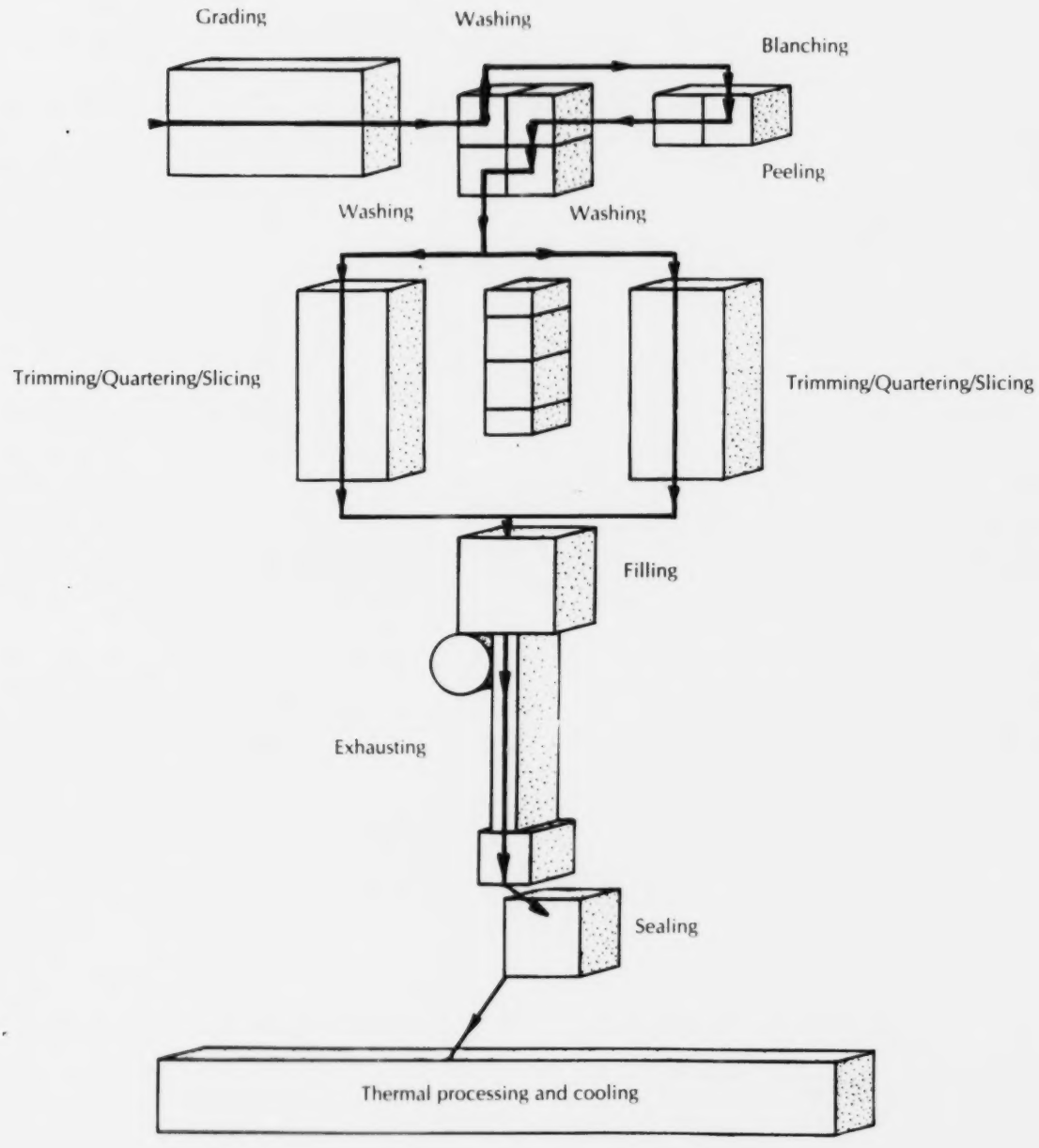
Fungi

Yeasts



Molds

Carrot Canning Line



Activity 1: Reducing Food Spoilage and Waste

Procedure

1. In this activity, you will work in lab groups to compare the spoilage rate of carrots that have been canned in different ways. You will need:

- 1 balance
- 2 beakers (500-mL)
- 2 fresh carrots of the same size and appearance
- 1 cutting board
- distilled water (200 mLs)
- 1 hot plate
- 4 jars (baby food or small canning, with lids)
- 1 sauce pan
- 1 petri dish
- 1 scalpel
- NaCl (table salt, 10 g)
- 1 pair of tongs
- 1 vegetable peeler

Make sure all equipment and utensils are clean. Leave the lids on the jars until you are ready to use them. Check the jars to be sure there are no cracks in them. Wash your hands thoroughly using anti-bacterial soap and water before starting the activity.

Safety Tips: Wear goggles for this activity. Exercise caution when cutting the carrots. Do not eat any of the carrots before, during, or after the activity. Do not drop carrot disks into boiling water; slip them in carefully. Wear oven mitts when handling hot jars.

2. Mass the carrots and record the total mass in the chart "Mass of Carrots and Organic Waste," page 12.

3. Prepare the control/treatment jars.

a) Use the vegetable peeler to peel two carrots. With the scalpel, remove the root tip from the pointed end of the carrot and all of the green from the stem end. Place the peels and ends in the petri dish and set aside.

b) Cut the carrots into one-centimeter disks. Place equal amounts of carrots in each of the four jars. Add 50 mLs of distilled water to each jar.

c) Attach the lid to one of the jars. Label this jar "control." Set aside the other three jars for specific treatments described in the following steps.

4. Prepare the salt only treatment.

a) Add five grams of salt to the liquid in the second jar. Attach the lid and swirl gently to completely dissolve the salt.

b) Label this jar "salt only."

5. Prepare the thermal treatment.

a) Attach the lid tightly to the third jar of carrot disks.

b) Set the jar in the saucepan and cover the jar with water.

c) Set the saucepan on the hot plate and bring the water to a boil. Turn off the hot plate. Leave the jar of carrots in the hot water.

d) After 15 minutes, use the tongs to remove the jar from the water and set aside gently to cool at room temperature. Exercise caution; the jar will still be hot. Wear oven mitts for this step.

e) Label the jar "thermal only."

6. Prepare the thermal plus salt treatment.

a) Add five grams of salt to the liquid in the fourth jar. Attach the lid tightly. Swirl the jar gently to completely dissolve the salt.

b) Set the jar in the saucepan and cover the jar with water.

c) Set the saucepan on the hot plate and bring the water to a boil. Turn off the hot plate. Leave the jar of carrots in the hot water.

d) After 15 minutes, use the tongs to remove the jar from the water and set aside gently to cool at room temperature. Exercise caution; the jar will still be hot. Wear oven mitts for this step.

e) Label this jar "thermal plus salt."

7. Set all four sealed jars in the same location. Compare the appearance of the carrot disks in the treatment jars with the control. Record your initial observations in the chart "Food Spoilage and Waste," page 12.

8. Record the total mass of the peels and the ends in the chart "Mass of Carrots and Organic Waste." (Be sure to deduct the mass of the petri dish from the total.)

Collecting and Analyzing Data

1. Calculate the organic waste percentage (peels and ends) using the formula:

$$\frac{\text{total mass of peels and ends}}{\text{total mass of carrots}} \times 100$$

2. Every few days for two weeks, observe the four jars of carrots you prepared. Do not take the lids off the jars. Record your observations in the chart "Food Spoilage and Waste," especially noting any changes you see. After two weeks, compare your carrots with those from other groups. Prepare a persuasive presentation on the environmental impact of food spoilage and waste. Support your viewpoint with scientific principles learned from the *Background: Student* and your research.

Mass of Carrots and Organic Waste

Mass of carrots, g (A)	Mass of peels and ends, g (B)	Percentage of organic waste (B/A x 100)

Food Spoilage and Waste

Observe and record the appearance of the carrots immediately after canning, and then every few days for a two-week period.

Date	Control	Salt only	Thermal only	Thermal plus salt

Drawing Conclusions

1. Which treatment(s) provided the most resistance to food spoilage? Why? Describe the role of canning in reducing food waste.
2. What improvements in food processing would further reduce the amount of food spoilage and waste created each day? Consider both organic and packaging waste.

Activity 2: Space Food

Objectives

Presented with information and charts on food processing and packaging technologies, the learner will participate in designing, analyzing, and recommending improvements to a system for serving food in space, by:

- analyzing the effect of two variables — gravity and limitations in physical space — on a food serving system
- formulating plans that can be used to accommodate the conditions for eating in space
- developing possible courses of action in response to the risks of food spoilage and waste
- designing and constructing a food serving system for extending the ease and comfort of eating in space

Time

One class period

Safety Tips

During the anti-gravity test, volunteers should wear goggles to prevent food from falling in their eyes, and eat and drink slowly to prevent choking.

Materials/Equipment

Balances or scales

Drinking straws or plastic tubing

Fasteners (strip magnets, tape, self-gripping fasteners)

Food and beverages (assortment of single serve packages; e.g., tuna, pudding, vegetables in cans with lift tops, dried apricots, juice in boxes, macaroni and cheese in pouches)

Food trays or muffin pans (assorted, steel or plastic)

Goggles

Plastic sheets

Plastic raincoat

Scissors

Shower cap

Utensils for eating

Figures/Tables

Types of Space Foods, page 15

Typical Shuttle Menu Selection, page 16

Procedure

1. Copy *Types of Space Foods* and *Typical Shuttle Menu Selection* onto transparencies, or use as handouts. Use the figures and the *Background: Student*, pages 5 and 6, to discuss how food processing and packaging help meet the demand for safe, nutritious foods in space.

2. Divide the class into groups of three or more. Provide each group with a balance or scale, food and beverage for a balanced meal, a pair of goggles, a plastic sheet, a plastic raincoat, and a shower cap. Make available an assortment of drinking straws or plastic tubing, fasteners, food trays or muffin pans, and eating utensils. Lab groups will choose from these items to design and construct a space food securing system.

3. Copy and provide to each student *Activity 2: Student*, pages 17 and 18. Review the steps for designing the food securing system and performing the anti-gravity test. Instruct lab groups to proceed with the activity.

Collecting and Analyzing Data

1. At the conclusion of each anti-gravity test, instruct students to mass the amount of food dropped, observe the amount of beverage spilled and describe the efficiency of the tray design system.

Ask students to record data and observations in the chart "Designing a Space Food Serving System," page 18.

2. Evaluate the techniques used by the groups who had the least amount of wasted food and beverage and provided the most successful system for securing the food, beverage and utensils.

   Lead a class discussion comparing student designs with the food tray used on shuttle missions. Refer to the food tray in *Types of Space Foods*. Point out the components:

- Square bowls snap into place in the tray. Water may be injected through a corner hole in each bowl to rehydrate the food.
- Cans and foil beverage packages fit into slots in the tray.
- The tray is magnetized to hold eating utensils. It may be attached to an astronaut's lap by a strap or attached to a wall.
- After the meal, food containers are crushed in a trash compacter. Eating utensils and food trays are cleaned with premoistened towelettes.

Drawing Conclusions

Q1: *Why is it necessary for food taken on a space flight to be processed and packaged? Which areas of science would you assume were involved in space food technology? List the scientists involved and examples of their tasks for each science area.*

A1: Food must be processed and packaged for ease of transport, to ensure food safety and to avoid spoilage and waste. On a space flight, there is little room to discard waste and no opportunity to replace spoiled food.

The areas of science, scientists and tasks involved in space food technology include, but are not limited to:

Biology

Scientists: medical doctors and specialists, dieticians, botanists, food producers.

Tasks: plan menus to provide balanced diets, monitor health and nutritional needs, grow foods that are high in nutritional value.

Physics

Scientists: engineers, packaging designers.

Tasks: design packaging, eating and cooking utensils, food preparation equipment such as ovens and hydrators, storage areas and waste disposal systems.

Chemistry

Scientists: food chemists, hematologists.

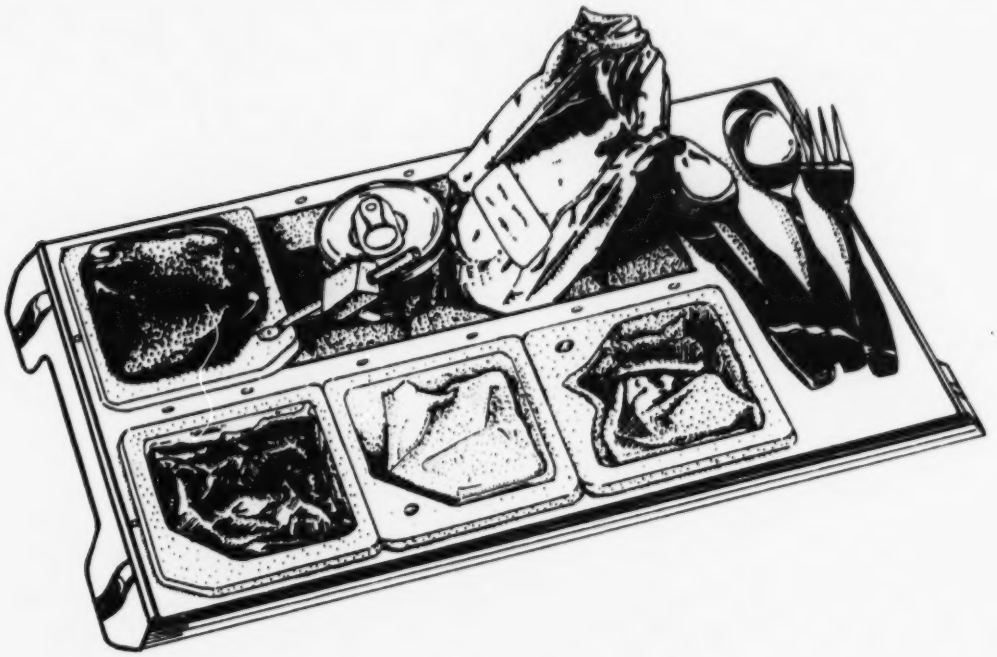
Tasks: test food for caloric and nutritional value, monitor body fluids to evaluate levels of health and nutritional deficiencies.

Q2: *How does food packaging technology affect the solid waste stream? Compare the United States with countries that have less sophisticated packaging systems.*

A2: Food packaging technology in the United States has contributed to a remarkably low food spoilage rate. Many parts of the world with less sophisticated packaging still have a serious problem with food safety and spoilage.

Discarded packaging, however, is a significant component of solid waste in the United States. The consumer can help reduce packaging waste by making a conscious effort to purchase products in packages that have recycled content and can be recycled locally.

Types of Space Foods



Fresh Food (FF)	Packaged in nitrogen with low moisture and low pH to prevent the growth of microorganisms.
Intermediate Moisture (IM)	Contains some moisture but not enough to support growth of microorganisms.
Irradiated Meat (I)	Cooked, packaged and sterilized by exposure to ionizing radiation.
Rehydratable (R)	Dried; requires water to become ready to eat.
Natural Form (NF)	Ready-to-eat.
Thermostabilized (T)	Heat processed to destroy microorganisms and enzymes.

Typical Shuttle Menu Selection

Meal A (Breakfast)

Dried apricots (IM)
Peach yogurt (T)
Cornflakes with milk (R)
Orange-grapefruit drink (R)

Meal B (Lunch)

Tuna (T)
Tortilla (FF)
Shortbread cookies (NF)
Almonds (NF)
Grape drink (R)

Meal C (Dinner)

Shrimp cocktail (R)
Beef steak (I)
Potatoes au Gratin (R)
Asparagus (R)
Tomatoes and Eggplant (T)
Grape drink (R)

Source: *NASA Facts: Food for Space Flight*. Prepared by Lockheed Engineering and Science Co. for Flight Crew Support Division, Space & Life Sciences, Lyndon B. Johnson Space Center, Houston TX. (Publication date not available.)

Activity 2: Space Food

Procedure

1. In this activity, you will work in lab groups to design a food serving system and demonstrate eating a meal in space. You will need:

   - 1 balance or scale
   - 1 pair of goggles
   - 1 plastic sheet
   - 1 plastic raincoat
   - 1 shower cap

   You may choose from the following, depending upon your design:

   - drinking straws or plastic tubing
   - fasteners (magnets, tape, or self-gripping)
   - food and beverage for a balanced meal, in individual, single serve packages
   - food tray or muffin pan (steel or plastic)
   - utensils for eating (steel or plastic)

> Safety Tips: The "astronaut" in this activity should eat and drink slowly, and wear goggles.

2. Design the food serving system.

a) With your group, discuss the characteristics of a system for serving a balanced meal to an astronaut in space compared to serving a meal on Earth. Consider the effect of two variables — gravity and physical space for food storage and waste disposal.

b) As a group, decide on the tray design. Select the food and beverage, tray, fasteners, utensils, and either a drinking straw or plastic tubing.

c) Collect the materials and assemble the food serving system, attaching each food item, beverage and utensil to the tray.

d) Sketch your system in the chart "Designing a Space Food Serving System," page 18. Write a brief description of how your system accommodates the lack of gravity and physical space encountered on a space mission. Label each food and beverage item and indicate:

- The processing method. For assistance in determining the processing method, refer to *Types of Space Foods*, page 15, and *Typical Shuttle Menu Selection*, page 16.
- The type of packaging (e.g., steel can, aluminum can, plastic cup, glass bottle, paper carton, foil pouch).

3. Anti-gravity test.

   Participate in a contest with other groups to evaluate the effectiveness of the food serving systems. Choose an astronaut and two technicians from your group. Perform the following as other groups observe:

a) The astronaut should wear a space suit (goggles, plastic raincoat and shower cap). Place a sheet of plastic on the floor. The astronaut should lie on the plastic, face up.

b) The technicians should position themselves on either side of the astronaut, and hold the food tray upside down and comfortably within arm's reach of the astronaut.

c) When ready, the astronaut should begin eating and drinking (slowly, to avoid choking), and continue until all the food and drink are consumed (or as much as the astronaut can comfortably consume).

Collecting and Analyzing Data

1. At the conclusion of each anti-gravity test, mass the amount of food dropped, observe the beverage spilled, and describe the efficiency of the tray design system. Record data and observations in the chart "Anti-gravity Test," page 18.

2. Participate in a class evaluation of the various food serving systems. Analyze the techniques used by the group that had the least amount of wasted food and beverage and provided the most successful system for securing the food, beverage and utensils. Compare the class systems with the system actually utilized on a space shuttle.

Designing a Space Food Serving System

Sketch your food serving system and briefly describe how it accommodates eating in space. Label each food and beverage item and indicate for each the processing method and type of packaging.

Anti-gravity Test

Group	Food waste, g	Beverage waste, estimated mL	Observations
1			
2			
3			
4			
5			
6			

Drawing Conclusions

1. Why is it necessary for food taken on a space flight to be processed and packaged? Which areas of science would you assume were involved in space food technology? List the scientists involved and examples of their tasks.
2. What effect has food packaging technology had on solid waste? Compare the United States with countries that have less sophisticated packaging systems.

Lesson: Collect & Haul

In this lesson, students will develop a better understanding of solid waste management, by long-term collection of leachate from decaying organic matter, and construction and maintenance of a worm box for composting organic matter as an alternative to hauling it to a landfill.

Objectives

Activity 3. Leachate Collection

The learner will develop an evidence-based position regarding the issue of leachates from landfills, by:

- constructing and testing models of leachate collection systems with soil type and organic waste as variables
- formulating hypotheses to explain differences in leachate production
- collaborating with other class members to perform an investigation over an extended period of time
- showing how effective leachate management practices may reduce the risk from leachate runoff into groundwater

Activity 4. Composting with Worms

The learner will gather data and develop a position on the issue of solid waste management, by:

- constructing a worm composting box and comparing it over time to a control box
- formulating hypotheses to explain the components that led to growth or lack of growth of worms in the box
- describing possible courses of action in response to issues of solid waste management
- writing environmental impact statements about worm composting boxes and municipal solid waste

Key Terms

Key terms are highlighted in the *Background: Student* with definitions provided in the *Glossary*.

composting **integrated solid waste management**
macroinvertebrate **methane**
sanitary landfill **leachate**

Motivation

Create an "Incredible, Edible Landfill" in a pie pan. Use a graham cracker pie crust as the clay base; fruit roll-ups as plastic liners; licorice rope as the leachate collection system; granola as gravel; vanilla pudding mixed with peanuts or raisins as solid waste; pretzel sticks as the gas recovery system; graham cracker crumbs as soil/sand; and shredded coconut dyed green with food coloring as grass planted on the landfill when it is filled and closed. Refer students to *The Sanitary Landfill*, page 21, as you build the landfill layer by layer. Allow students to eat the results.

Source: "Incredible, Edible Landfill." *Working on Waste*. University of Minnesota Extension Service Publication # 4H-BU-6064-S, 1992.

Demonstration

Display examples of nature- and human-generated waste. Ask students to brainstorm ways these items could be reused or recycled. For example, nature-generated waste such as deer antlers provide calcium to small rodents who nibble on the antlers; dead leaves provide food for microorganisms; dead tree limbs provide shelter and food for a host of organisms, large and small. Human-generated waste such as steel and aluminum cans, plastic and glass containers, food, and paper can be reused, recycled , composted or burned to produce electricity.

Content Development

Copy onto transparencies or use as handouts the figures *Characterization of the Municipal Solid Waste Stream by Material*, page 3, *The Sanitary Landfill*, page 21, and *Organisms in a Compost Pile*, page 22. Copy and distribute to each student the *Background: Student*, pages 23 and 24. Display the transparencies and use the background reading as references in discussing integrated solid waste management and the conservation of natural resources.

Extension

The following activity expands on concepts introduced in this lesson.

Reducing Cafeteria Food Waste

Cooperate with the principal, teachers, food service staff, and custodians to organize and conduct a one-day cafeteria food waste audit at your school. Place a container lined with a plastic garbage bag next to the regular waste receptacles in the cafeteria. Label the container "FOOD." Have student volunteers assist other students in depositing all food waste in the container. After the lunch period, mass the food waste.

With the class, brainstorm methods for reducing the amount of food waste. (e.g., Eat all your lunch, or build a large worm composting box for the school. The new soil may be used on the school grounds or sold to a landscaping company). Formulate a waste reduction plan for the school and prepare a public service announcement to inform and involve all students. Organize student groups and assign tasks. After several weeks, repeat the waste audit to determine whether the plan is working. For more information on waste audits, see "Mining Our Landfills?" in *Cycles for Science: General Science and Earth Science.*

Independent Study

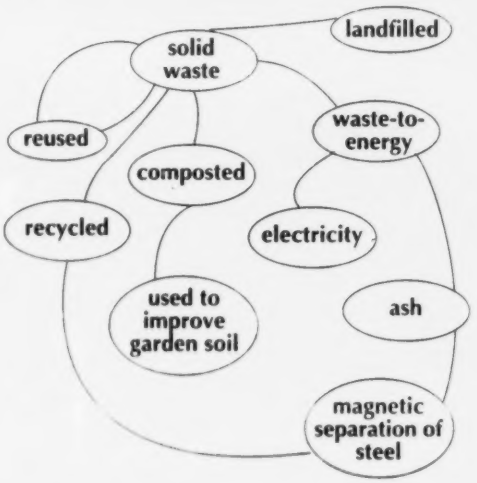
Contact your local public service organization or solid waste office for information on solid waste management in your community. Inquire about programs for recycling, composting, waste-to-energy and landfilling, including leachate and methane collection systems. Use a variety of media to construct a display and prepare a presentation for the class and other school groups.

Perform a microscopic survey of invertebrates in the worm box, or refer to the figure *Organisms in a Compost Pile*, page 22. Select an invertebrate and research its natural history. Prepare a report to share with the class.

Evaluation "Test Your Knowledge"

Evaluate learner understanding of the concepts introduced in this lesson. "Test Your Knowledge" suggestions:

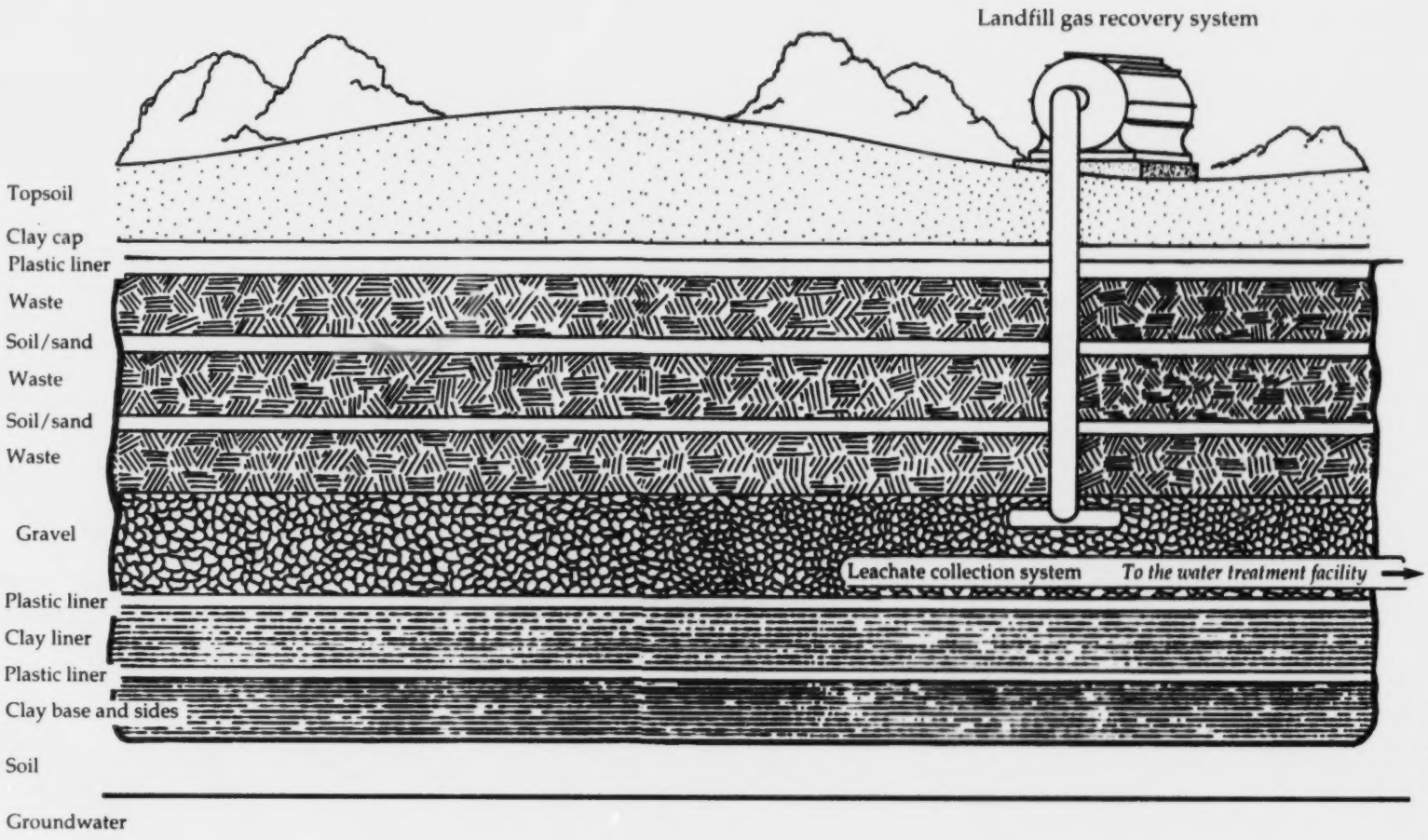
- Create a concept map of solid waste management options.



- Explain how good practices in solid waste management can help ensure a future supply of natural resources.

- Write a letter to the editor in which you describe how compost can be produced by worms. Include a statement expressing your views on the potential for reducing solid waste by composting, and how easy it is for each citizen to be involved.

The Sanitary Landfill



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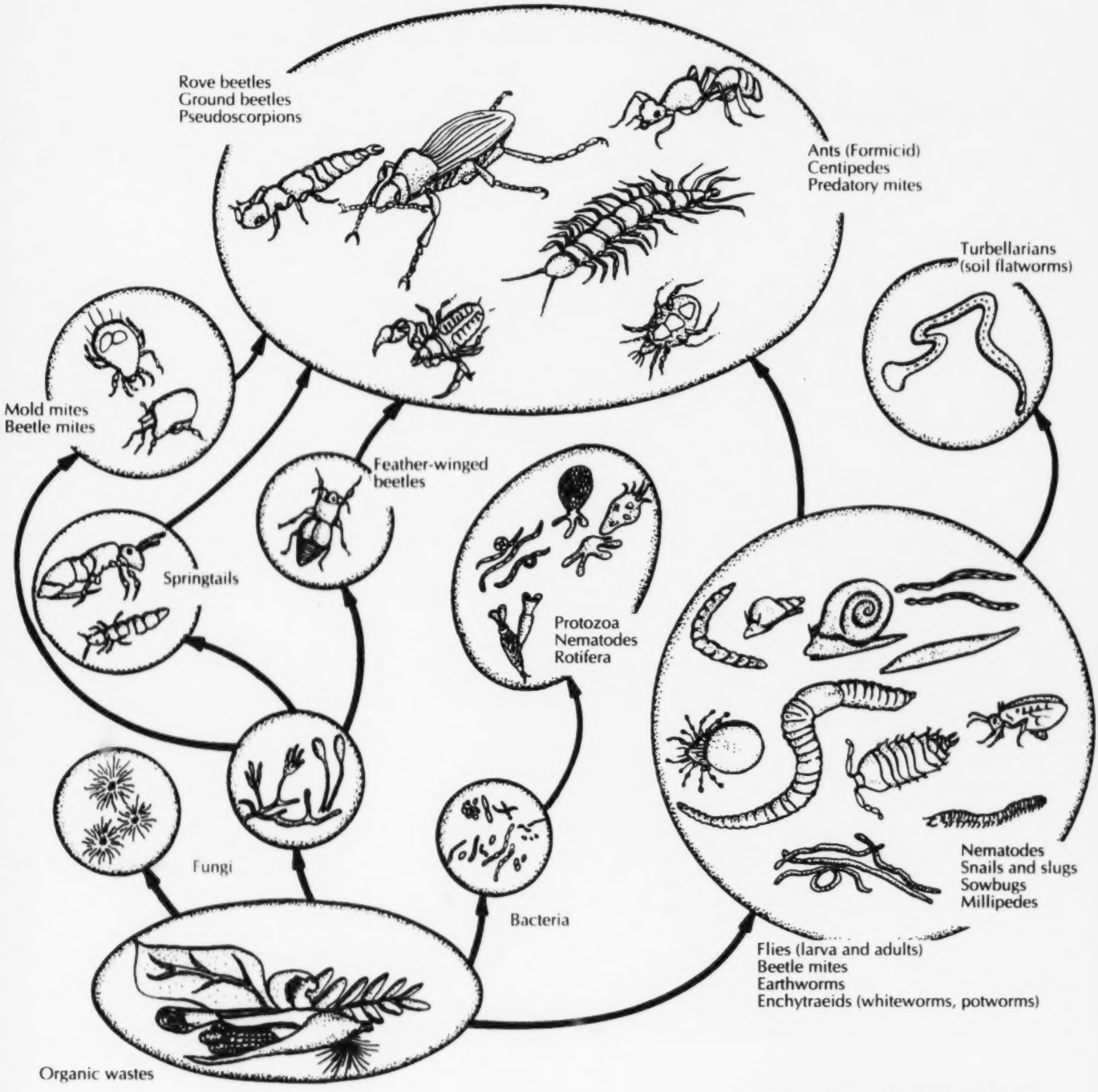
Background: Transparency

Organisms in a Compost Pile



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Arrows show the direction of the food chain

Source: Appelhof, Mary. *Worms Eat My Garbage*. Kalamazoo, MI: Flower Press, 1982.

Lesson: Collect & Haul

HAVE YOU EVER WONDERED?

How our waste disposal habits today can affect the availability of resources in the future?

One way to conserve natural resources, prevent pollution and preserve natural areas is to responsibly manage the solid waste that we produce. Many people in urban and suburban areas are accustomed to setting their trash out by the curb for the local solid waste authority to collect and haul away. Most people are unaware of what happens to the trash after it is picked up, or where it is disposed of.

Our system of municipal solid waste collection was established at the turn of this century. Prior to that, people disposed of their own waste, often throwing or sweeping it out into the street, or, in more modern times, burying it somewhere nearby. After municipal waste collection systems were established, solid waste generally was hauled to a town dump and forgotten. Due to increasing environmental concerns, disposing of waste is no longer quite so simple. We have learned that many of the older landfills are environmentally hazardous because when they were built there were no controls on where they were located, how they were constructed, or what was deposited in them. Consequently, all sorts of contaminants are leaking out of these landfills and polluting the groundwater, soil and air.

New U.S. Environmental Protection Agency (EPA) regulations require that **sanitary landfills** be carefully engineered and equipped with safety features that include **leachate** and **methane** control systems.

Leachate is water that has percolated down through the landfill, picking up solutes from the trash. Solutes may include toxic substances, heavy metals, viruses and bacteria, all of which may be dangerous if allowed to enter groundwater supplies.

Typically, a leachate collection system consists of perforated drainage pipes connected to a pump. Leachate that trickles into the pipes is pumped out of the landfill to a water treatment facility for purification. Landfills are required to monitor nearby groundwater to ensure that the leachate control system is working.

When solid waste is deposited in a landfill, it is compacted to save space and covered with soil or other material so that the waste is permanently contained, and moisture cannot easily enter the landfill and contribute to leachate. Because of the cover, however, oxygen cannot permeate into the landfill and decomposition of organic waste, such as food or yard clippings, eventually becomes anaerobic. The decomposition process produces what is commonly called landfill gas — predominately methane, with carbon dioxide and trace amounts of other organic gases.

If landfill gas is allowed to accumulate, it may cause explosions and offensive odors. To keep gases from building up in the landfill, perforated pipes are stuck down through the landfill from the surface, providing a vent for the gas to escape into the atmosphere. Many landfills have systems for collecting landfill gas as it is vented. This gas can be sold as a medium-grade fuel for producing electricity, or as a substitute for natural gas used by industrial customers. It also can be upgraded to natural gas pipeline standards and sold to a local gas utility company.

An Integrated Approach

Because there are so many people generating so much waste (180 million tons in 1990, according to a study conducted by Franklin Associates, Ltd., for the U.S. EPA), some existing landfills are becoming too full to handle the volume of waste produced. It is difficult and expensive to site and build a new landfill. Consequently, many communities are turning toward **integrated solid waste management** to reduce reliance on landfills.

Integrated solid waste management involves examining a variety of options and selecting the combination of methods that achieves the most efficient disposal of solid waste. Depending upon the facilities available to the municipality, options can include:

Source reduction — creating less waste to begin with, such as buying only what you need, using a product more than once or selecting items produced with the least amount of waste.

Recycling — collecting scrap materials such as steel, glass, plastic, aluminum or paper, and using them to manufacture new products.

Composting — collecting organic wastes, allowing them to decompose under controlled conditions, and adding the resulting compost to soil to improve its properties.

Waste-to-energy — hauling mixed solid waste to a facility where it is shredded and burned to generate electricity, after which steel is magnetically collected from the resulting ash for recycling.

Landfilling — hauling solid waste to a site that has been engineered to contain municipal solid waste with minimum impact on the environment.

Besides saving landfill space, integrated solid waste management promotes the conservation of natural resources. For instance, for each metric ton of steel recycled, 1029 kilograms of iron ore, 412 kilograms of coal, and 16 kilograms of limestone are saved. This is a significant savings in natural resources, since, according to the International Iron and Steel Institute, the 1991 world consumption (recycling) of scrap steel was 304 million metric tons. (The total world consumption of finished steel in 1991 was 628 million metric tons.)

Composting Organic Waste

Organic waste (food and yard waste) makes up approximately 28 percent of the municipal solid waste in the United States, amounting to 40 million metric tons in 1990. Of this, 28 million metric tons were yard trimmings and 12 million metric tons were food waste. Many municipalities have begun to ban yard trimmings from landfills, encouraging people to leave grass clippings on the lawn and to compost leaves in backyard compost piles or at commercial composting facilities. Food waste generally is still accepted by municipalities, but if done properly, vegetable scraps can also be composted in a backyard compost pile. (Contact your local health department or solid waste office for regulations on food composting.) Some states have initiated programs for assisting homeowners in setting up compost piles.

A well-constructed compost pile will contain many organisms that rapidly decompose organic waste. The interior portions of the pile may become quite hot during decomposition, and support only heat tolerant fungi and bacteria. Cooler portions of the pile may contain a wider variety of organisms, including earthworms.

How Worms Work

Earthworms are **macroinvertebrates** (organisms that do not have a backbone and can be seen without the aid of a microscope). Worms live in moist terrestrial habitats and require aerobic conditions because they "breathe" by diffusion of gaseous oxygen across the moist tissue of the skin. Worms cannot see, but sensory cells in the skin are sensitive to light, particularly at the anterior (front) end. The mouth of a worm is located in the anterior end. Worms have no teeth, and are limited to food that is small enough to draw into the mouth. Usually this food is softened by moisture or by microorganisms. Worms have a muscular gizzard that functions similarly to that of a bird. When food is ingested, small grains of sand and minerals are taken in also, helping grind the food as the muscles of the gizzard contract.

The ground-up food enters the intestine, which secretes digestive enzymes. The enzymes further digest the food, which then passes through the intestinal wall to be absorbed into the bloodstream and transported where needed. Undigested material, such as soil, bacteria and plant residues, pass out of the worm through the anus at the posterior (rear) end. These castings are useful as a soil conditioner.

Activity 3: Leachate Collection

Objectives

The learner will develop an evidence-based position regarding the control of leachates in landfills, by:

- constructing and testing models of leachate collection systems, with soil type and organic waste as variables
- formulating hypotheses to explain differences in leachate production
- collaborating with other class members to perform an investigation over an extended period of time
- explaining how effective leachate management practices may reduce the risk from leachate runoff into groundwater

Time

One class period to assemble
Three weeks for results, with weekly observations

Safety Tips

Remind students to exercise caution when cutting the bottles.

Materials/Equipment

Bottles (clear plastic beverage, 2-liter)
Cheesecloth
Markers (permanent)
Organic waste (grass clippings or shredded vegetable scraps, possibly obtained from Activity 1)
Plastic wrap
Rubber bands
Scissors
Soil (clay, potting, sand and gravel)
Tape (clear plastic)
Water

Figures/Tables

The Sanitary Landfill, page 21

Procedure

1. Use the figure *The Sanitary Landfill*, page 21, and the *Background: Student*, pages 23 and 24, to discuss options for integrated solid waste management and the components of the sanitary landfill. Review the process and products of decomposition. For more information on decomposition, refer to a standard biology text.

2. Divide the class into lab groups. Assign each group one of the following soils. If the class is large, you may assign the same soil to more than one group to replicate the experiment.
   - Clay
   - Potting soil
   - Sand
   - Gravel

   Provide each group with two 2-liter plastic beverage bottles, two 10-centimeter squares of cheesecloth, a permanent marker, 500 mL of organic waste, two 30-centimeter squares of plastic wrap, two rubber bands, scissors, one liter of the assigned soil, tape and 200 mL of water.

3. Copy and distribute to each student *Activity 3: Student*, pages 27 and 28. Review the procedures and instruct lab groups to proceed with constructing their leachate collection systems.

   Note: If students have difficulty getting started with cutting the bottles, use a knife or scalpel to make an incision large enough to insert the scissors tip in the bottle.

4. Designate an area to store the leachate collection systems. It is important that all the systems are exposed to the same environmental conditions.

5. *For further study:*

- Perform chemical tests on leachates from the model leachate collection systems.

- Observe microorganisms in the soil and the decomposed organic waste. Be careful not to touch or inhale any microorganism spores.

- Encourage students to design and perform experiments to answer questions raised during the activity.

  For example, students may wonder whether the initial water content of the soil affected leachate production. They may suggest drying the soils in a drying oven prior to beginning the experiment.

  Or, students may wonder how rain affects the landfill. They may suggest pouring ten mL of water in each system each time it rains outdoors.

Collecting and Analyzing Data

1. Provide opportunities for students to observe the systems over a period of three weeks. Instruct them to record observations on the appearance of the soil, organic waste and leachate.

2. After three weeks, instruct students to measure the volume of leachate produced in each system. Ask them to compare systems and indicate on the chart which one produced the most leachate.

Drawing Conclusions

Q1: *Examine* The Sanitary Landfill, *page 21. Why is clay used at the bottom and the sides of the landfill? Why is the leachate collection system embedded in gravel?*

A1: Because clay holds water, and is relatively impermeable to it, it is used on the bottom and sides of a landfill to prevent leachate from flowing into nearby groundwater. The leachate collection system is embedded in gravel because gravel does not hold water; leachate can move freely through gravel into the collection pipes.

Q2: *What are some sources of leachate in a landfill? How could you as an individual reduce leachate in a landfill?*

A2: Sources of leachate in a landfill include organic waste, liquids deposited in the waste stream, and any rainwater which enters the landfill in spite of the soil or plastic cover. Organic waste generally contains a high percentage of water, which is released as decomposition occurs.

Individuals can help reduce leachate in landfills by composting organic waste and by avoiding throwing even small amounts of liquid in the trash. Small amounts of liquids thrown away by individuals add up to significant volumes in the landfill.

Note: Students may be aware that some excavations in landfills reveal materials that have not decomposed after many years because of the anaerobic conditions. *(See Rubbish! The Archaeology of Garbage*, listed in the *Appendix: Bibliography*, page 54.) Landfills are designed to minimize decomposition, thereby avoiding landfill gas production. Nevertheless, the rate of decomposition and the shear volume of organic waste deposited in landfills is high enough to contribute significantly to leachate from organic materials. Many communities are banning some types of organic waste, particularly grass clippings and other yard waste, from landfills.

Activity 3: Leachate Collection

Procedure

1. In this activity you will work with your lab group to construct two model systems for collecting and measuring leachate produced by decomposition of organic waste, as might occur in a landfill. Your teacher will assign your group one soil — clay, potting soil, sand or gravel — to use in your systems. You will need:

- 2 clear plastic beverage bottles (2-liter)
- 2 squares of cheesecloth (10-cm)
- 1 permanent marker
- organic waste (shredded vegetable scraps or grass clippings, 500 mL)
- 2 squares of plastic wrap (30-cm)
- 2 rubber bands
- scissors
- the soil assigned to you by your teacher (1 liter)
- clear plastic tape
- water (200 mL)

Safety Tips: Exercise caution when cutting the bottles. If you have difficulty getting the cut started, ask your teacher to make an incision in the bottle with a sharp knife or scalpel.

2. Assemble your model leachate collection systems. Refer to the figure *"Scheme of a Leachate Collection System."*

Scheme of a Leachate Collection System

a) Cut the plastic bottles in half as shown.

b) Secure a square of cheesecloth with a rubber band over the mouth of each bottle.

c) Invert the top section of one bottle into its base, leaving approximately three centimeters of space at the bottom. Tape the seam to hold the inverted section in place. Repeat for the second bottle.

3. Prepare the control system.

a) Add 500 mL of soil to one system. Do not pack down the soil.

b) Add 100 mL of water to the system.

c) Cover the open end of the bottle with plastic wrap and secure with tape.

d) Label this system with the soil type and "control."

4. Prepare the organic waste system.

a) Add 400 mL of soil to the second system. Do not pack down the soil.

b) Add the organic waste to the system. Layer it on top of the soil.

c) Cover the organic waste with the remaining 100 mL of soil.

d) Add 100 mL of water to the system.

e) Cover the open end of the bottle with plastic wrap and secure with tape.

f) Label this system with the soil type and "organic waste."

5. Set both systems in the location designated by your teacher.

Collecting and Analyzing Data

1. Observe the systems constructed by each group. Record your initial observations on the soil, organic waste and leachate in the chart "Observations on Leachate Collection Systems," page 28. Repeat your observations each week.

2. After three weeks, record the volume of leachate produced in each system. Compare systems and indicate on the chart which system produced the most leachate.

Observations on Leachate Collection Systems

System	Observations (color, texture, etc.)				Volume of leachate after 3 weeks, mL
	Initial	Week 1	Week 2	Week 3	
Clay: control					
Clay: organic waste					
Potting soil: control					
Potting soil: organic waste					
Sand: control					
Sand: organic waste					
Gravel: control					
Gravel: organic waste					

Drawing Conclusions

1. Examine *The Sanitary Landfill*, page 21. Why is clay used at the bottom and the sides of the landfill? Why is the leachate collection system imbedded in gravel?
2. What are some sources of leachate in a landfill? How could you as an individual reduce the amount of leachate in a landfill?

Activity 4: Composting with Worms

Objectives

The learner will gather data and develop a position on the issue of solid waste management, by:

- constructing a worm composting box and comparing it over time to a control box
- formulating hypotheses to explain the components that led to growth or lack of growth of the worms in the box
- describing possible courses of action in response to issues of solid waste management
- writing environmental impact statements about worm composting boxes and municipal solid waste

Time

One class period to assemble

Eight weeks for results with occasional maintenance and observation

Materials/Equipment

Balances
Containers for distributing worms (clean steel food cans containing moist sawdust or shredded newspaper)
Garden fork
Glue
Newspapers
Plastic lids from gallon jugs
Pizza box lids
Plastic buckets
Plastic sheeting (black, as from a garbage bag)
Redworms *(Eisenia foetida)*
Scissors
Shoe boxes with lids
Spray bottles for water (clean, with no chemical residues)
Tape (waterproof adhesive)
Vegetable scraps (steady supply of chopped or shredded carrot peels, fruit rinds, coffee grounds, etc. — no meat or bones)
Water
Optional: Acetate sheets (red)

Figures/Tables

Anatomy of an Earthworm, page 31
Scheme of a Worm Box, page 32

Procedure

1. Copy onto a transparency or use as a handout *Anatomy of an Earthworm*. Use the *Background: Student*, pages 23 and 24, to discuss composting as an option for waste management. Refer to the transparency to discuss the digestion process of earthworms. For more information on earthworm anatomy, refer to a biology text.

2. Divide the class into lab groups. Provide each group with a balance, glue, four lids from plastic milk jugs, the lid from a pizza box, a 60 x 40 centimeter sheet and a 60 x 60 centimeter sheet of black plastic, a six page section of newspaper, 15 redworms in a small container (about seven grams; be sure to keep the worms moist), scissors, a shoe box with lid, a spray bottle, waterproof adhesive tape, and 250 grams of vegetable scraps.

   To maintain the worm boxes over an eight week period, students will need a spray bottle with water and a continual supply of vegetable scraps (250 grams per lab group per week).

   Redworms *(Eisenia foetida)* are a type of earthworm that does well in warm conditions, such as a classroom and in the organic litter in a compost pile. Other worms require cooler conditions and more soil, and so may not be suitable for this activity. (Nightcrawlers, *Lumbricus terrestris*, require temperatures of ten degrees Celsius or cooler.) Redworms are available from bait shops and mail order catalogues.

3. Copy onto a transparency or use as a handout *Scheme of a Worm Box*, page 32. Copy and distribute to each student *Activity 4: Student*, pages 33 and 34. For more information on worm boxes, refer to *Worms Eat My Garbage* by Mary Appelhof, listed in the *Appendix: Bibliography*, page 54.

4. Demonstrate the procedures by setting up a worm box with no worms, to be used as a control. Add 250 grams of vegetable scraps each week.

5. Instruct lab groups to proceed with the activity. Every few days, allow time for students to check, observe, and maintain their worms. When the activity is completed, release the worms in a garden, home composting pile or a greenhouse. If releasing the worms outdoors, make sure the weather is warm to avoid shocking the worms with a sudden change in temperature.

   The activity is designed for eight weeks, but worm boxes may be maintained indefinitely if the bedding is replenished periodically and excess worms are transferred to another worm box or a garden. See *Worms Eat My Garbage* by Mary Appelhof (see the *Appendix: Bibliography*).

6. *For further study:*

- Design an experiment to test the volume of compost produced per kilogram of vegetable scraps put in the worm box.

- Test the effect of worm compost on plant growth. Mix the compost from the worm boxes with soil and add to plants in a greenhouse or sunny window. Compare growth of plants with and without compost.

Collecting and Analyzing Data

1. After eight weeks, instruct lab groups to gently remove all the worms from the boxes, count the worms, and record the number in the chart "Change in Mass of Redworms," page 34. Assist students with massing the worms, calculating the average mass per worm, and determining the changes in total mass and mass per worm.

2. Ask students to observe the bedding material and record observations in the chart "Observations on Worm Bedding after Eight Weeks," page 34. Encourage them to compare the bedding in their worm boxes with the control.

Drawing Conclusions

Q1: *What conditions contributed to growth (or lack of growth) of the worms in the boxes? Explain. Are you likely to find many earthworms in a sanitary landfill? Why or why not? What other types of decomposers might you find in a landfill?*

A1: Conditions required for growth are a food source (vegetable scraps), moisture and air. Moisture is important to prevent worm dehydration, but too much moisture suffocates the worms. The drainage holes help to prevent suffocation. Students may have seen a high rate of worm mortality particularly if the moisture levels were too low.

You are not likely to find many earthworms in a sanitary landfill because the conditions tend to be anaerobic. Decomposers in a landfill generally are microorganisms such as the methanogens that require anaerobic conditions.

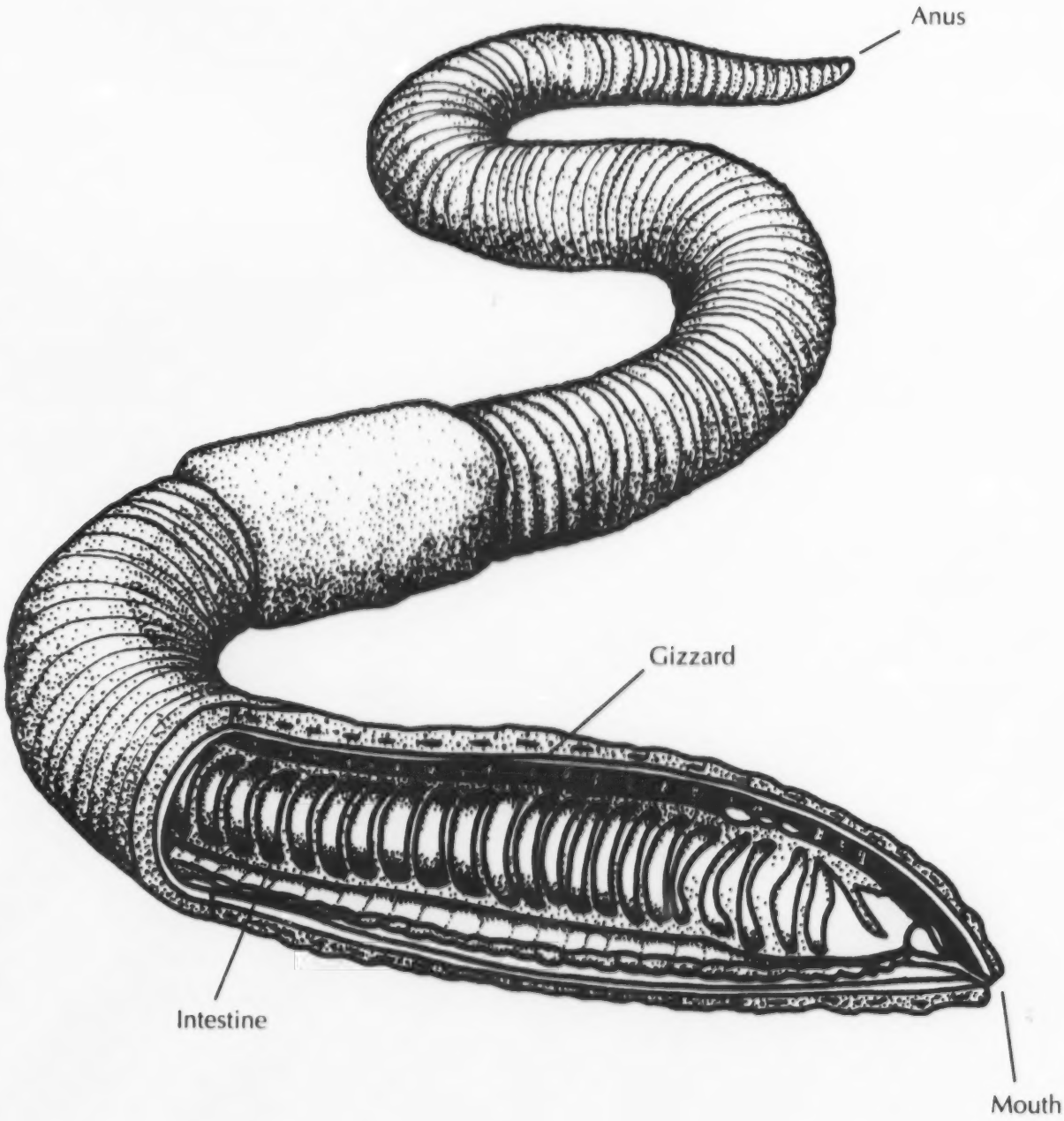
Q2: *If each household in your community had a worm box, and each person fed the worms 0.25 kilograms of food waste per week, how much organic waste would be diverted from the landfill per year? Compose an environmental impact statement regarding composting and municipal solid waste.*

A2: To calculate the diversion of organic waste from the landfill, students may use the formula:

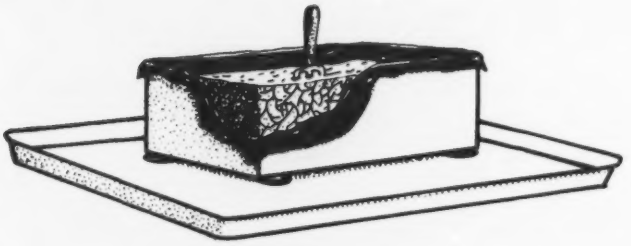
# of persons x 0.25 kg/person x
52 weeks/year

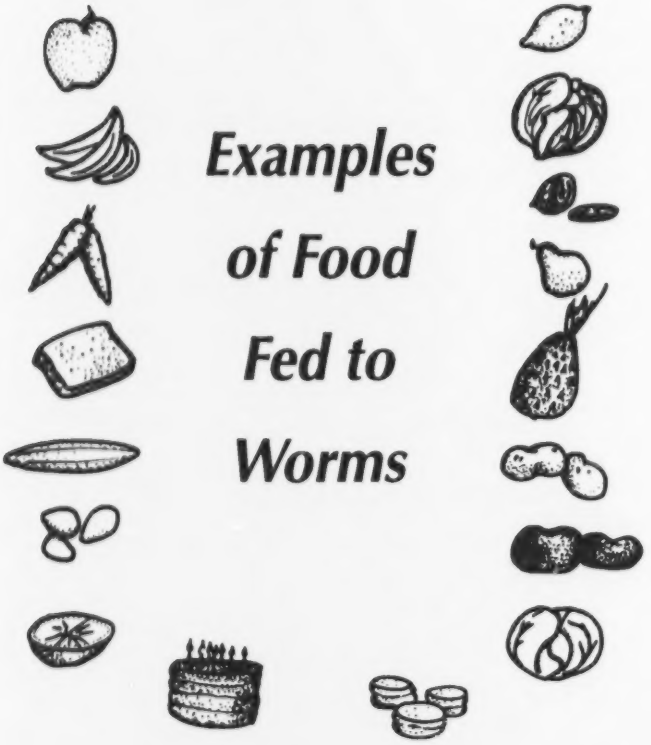
Students may refer to *Background: Student*, pages 23 and 24, data and observations collected from the activity, and other sources to compose an environmental impact statement regarding composting and municipal solid waste.

Anatomy of an Earthworm



Scheme of a Worm Box





Activity 4: Composting with Worms

Procedure

1. In this activity, you will work with your lab group to build and maintain a worm box for composting vegetable scraps. You will need:
   - 1 balance or scale
   - 1 garden fork
   - glue
   - 4 plastic lids from milk jugs
   - 1 lid from a pizza box
   - 6 sheets of newspaper
   - 1 plastic bucket
   - 1 sheet of black plastic (60 x 40 cm)
   - 1 sheet of black plastic (60 x 60 cm)
   - 15 redworms in a small container (be sure to keep the worms moist)
   - 1 pair of scissors
   - 1 shoe box with lid
   - potting soil (250 g)
   - 1 spray bottle
   - waterproof adhesive tape
   - vegetable scraps (250 g, shredded or chopped)
   - water (1 L)

2. Prepare the box. Refer to *Scheme of a Worm Box*, page 32.

a) Glue a plastic lid from a milk jug on each of the four corners on the outside bottom of the shoe box. This will allow drainage and air circulation under the box.

b) Line the inside of the shoe box with the 60 x 40 centimeter sheet of black plastic, overlap the sides, and tape it in place around the outside of the box.

c) Working from the inside of the box, use the scissors to punch ten or twelve 1/2-centimeter holes in the bottom of the shoe box. These holes will provide drainage and aeration. Punch through both the plastic and the box.

d) Make a drainage tray of the pizza box lid by lining it with the 60 x 60 centimeter sheet of plastic. Tape the plastic in place. If needed, reinforce the lid by taping the sides.

e) Set the shoe box on the tray.

3. Prepare the bedding.

a) Tear the newspaper into 3 x 30 centimeter strips and place them in the bucket. Sprinkle potting soil on top.

b) Add a liter of water to the shredded newspaper and soil. Stir the mixture until everything is evenly moist.

c) Transfer the bedding mixture from the bucket to the shoe box.

4. Introduce the worms into the shoe box.

a) Mass the redworms and the container. Record the mass in the chart "Change in Mass of Redworms," page 34.

b) Gently remove the worms from the container and place them on the bedding in the box. Count the worms and record the number in the chart. Leave the lid off the box. The worms will gradually move down into the bedding as they try to avoid light.

c) Mass the empty container. Record the mass in the chart "Change in Mass of Redworms."

d) Calculate the total mass of the worms and the average mass per worm.

e) Once the worms have moved down into the bedding, add the vegetable scraps. Rake the scraps into the bedding by stirring lightly with the fork.

f) Place the lid on the shoe box.

5. Maintain the worm box.

a) Check the worm box every few days for moisture. The bedding should be kept moist but not wet. Use a spray bottle to mist the bedding as necessary. To conserve moisture, be sure to keep the lid on the box.

b) Feed the worms once a week by gently raking 250 grams of shredded or chopped vegetable scraps into the top layer of bedding.

6. *Optional:* If a red sheet of acetate is available, tape it securely to the top of the box, making sure that no sunlight or lamplight leaks through. Leave the lid off the box. The worms will not respond to red light as they do to sunlight or lamp light, and you should be able to see them come to the surface to feed.

Collecting and Analyzing Data

1. After eight weeks, remove the worms from the box. Count and record the number of worms in the chart "Change in Mass of Redworms."

   Mass the worms and calculate the average mass per worm. Calculate the change in total mass, number of worms, and mass per worm.

2. Observe the bedding material and record your observations in the chart "Observations on Worm Bedding After Eight Weeks." Compare the bedding in your worm box with the control.

Change in Mass of Redworms

	Total mass,g			Number of worms (D)	Average mass per worm, g (D/C)
	Worms + container (A)	Empty container (B)	Total mass of worms (A - B = C)		
Starting					
Ending					
Change					

Observations on Worm Bedding after Eight Weeks

Worm box with worms	
Control (worm box without worms)	

Drawing Conclusions

1. What conditions contributed to growth (or lack of growth) of the worms in the boxes? Explain. Are you likely to find many earthworms in a sanitary landfill? Why or why not? What other types of decomposers might you find in a landfill?

2. If each household in your community had a worm box, and each person fed the worms 0.25 kilograms of food waste per week, how much organic waste would be diverted from the landfill per year? Compose an environmental impact statement regarding composting and municipal solid waste.

Lesson: Sort & Produce

In this lesson, students will examine the recycling process by classifying musculoskeletal levers and mechanical levers such as those used in sorting commingled recyclables, and by relating the colors produced during steelmaking to wavelength, temperature and anatomy of the human eye.

Objectives

Activity 5. Bones and Levers

The learner will compare and contrast levers in the human body with levers in machinery, by:

- recognizing and utilizing lever classification systems for exploring musculoskeletal and mechanical levers
- formulating hypotheses to explain the interaction of components of levers
- refining the use of mathematics skills by applying these skills in a scientific investigation
- investigating the working of tools that extend the limits of human capabilities

Activity 6. The Color of Hot Metals

The learner will conduct an investigation of the relationships among heat, wavelengths of visible light, and color, by:

- utilizing the chart of wavelengths of visible light to predict temperatures of flames and explain color changes as metals are heated
- formulating a description of the impact of electromagnetic waves on perception of color
- refining the use and understanding of the concepts of mass and specific heat
- comparing school-based science perspectives with technological applications

Key Terms

Key terms are highlighted in the *Background: Student* with definitions provided in the *Glossary*.

cone	**electromagnetic wave**
effort arm	**fulcrum**
resistance arm	**rod**

Motivation

Divide the class into teams of two. Give each team two or three brightly colored objects (e.g., balloons, colored plastic eggs). As one student (the viewer) looks straight ahead, the other student should slowly move one of the objects into the viewer's peripheral vision, starting from the back of the viewer's head and holding the object about 60 centimeters from the side of the viewer's head. The viewer should state 1) the moment when the object can be seen and 2) the moment when the object's color can be distinguished. Ask students to summarize their findings about peripheral vision and color.

Students will realize that they can detect a moving object with peripheral vision before distinguishing its color. After reading the *Background:Student*, pages 39 and 40, students should be able to explain that the color-receptive cones of the eye are concentrated primarily in the center of the eye. Consequently, objects to the side appear black.

Demonstration

Tie a rope to a door handle and ask a student volunteer to shake the rope up and down. Instruct the class to:

- Observe and describe the arm motions of the volunteer. What causes these motions? (The arm bends at the elbow and moves up and down at the shoulder. The motions are caused by muscles in the arm and shoulder contracting and pulling on the bones.)
- Observe and compare the "waves" as the rope is shaken slowly, then quickly. What is the relationship between speed and distance between waves? (As the rope is shaken slowly, the waves move slowly and are far apart. As the rope is shaken quickly, the waves move quickly and are closer together. There is an inverse relationship between speed and distance.)

Background: Teacher

Content Development

Copy and distribute to each student the *Background: Student*, pages 39 and 40. Copy onto transparencies or use as handouts the figures:

Example of Processing Recyclables at a Materials Recovery Facility, page 37
The Making of Steel, page 38
Musculoskeletal Levers, page 43
Classes of Levers, page 44
The Human Eye, page 49
Wavelengths of Visible Light, page 50

Use the *Background: Student* and the figures to discuss the recycling and making of steel. Describe mechanical and musculoskeletal levers and explain how the human eye perceives color. For more information on the human body and color emission, refer to standard biology and physics texts. For more information on materials recovery facilities refer to *Cycles for Science Physics*. For more information on steelmaking, refer to *Cycles for Science Chemistry, General Science and Earth Science*, and *Physics*.

Extension

The following activity expands on concepts introduced in this lesson.

Manual or Mechanical

Arrange a class tour of a local recycling facility or steel mill. Observe the machinery used. Compare and contrast the types of jobs that are done manually with those done mechanically. Prepare a presentation, and include a schematic similar to *Example of Processing Recyclables at a Materials Recovery Facility*, page 37.

Independent Study

- Research the field of robotics and prepare a presentation for your class. Include in your presentation the problems that must be addressed when designing robots to imitate fine human movements. Also include the use of computers, and the materials and metals that are used to make robots. Find out how robots are used in manufacturing plants.

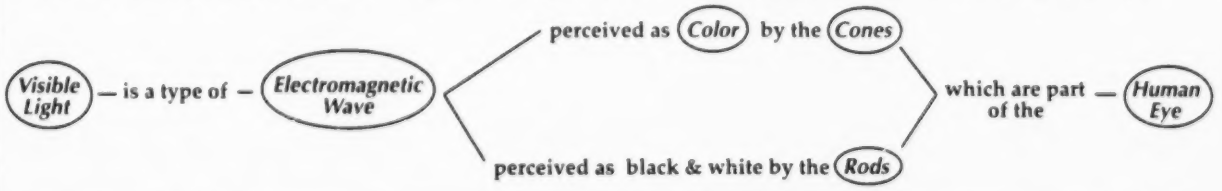
- Research the types of thermometers and methods used to measure extreme temperatures (molten steel, the sun, dry ice). Prepare a chart similar to *Wavelengths of Visible Light*, page 50, showing temperature extremes of items ranging from liquid nitrogen to the sun. Highlight the narrow range of air temperature and animal body temperatures.

Evaluation "Test Your Knowledge"

Evaluate learner understanding of the concepts introduced in this lesson. "Test Your Knowledge" suggestions:

- Locate a musculoskeletal lever and a lever in a machine. Identify the fulcrum, resistance arm, and effort arm in each lever. Classify and compare the two levers.

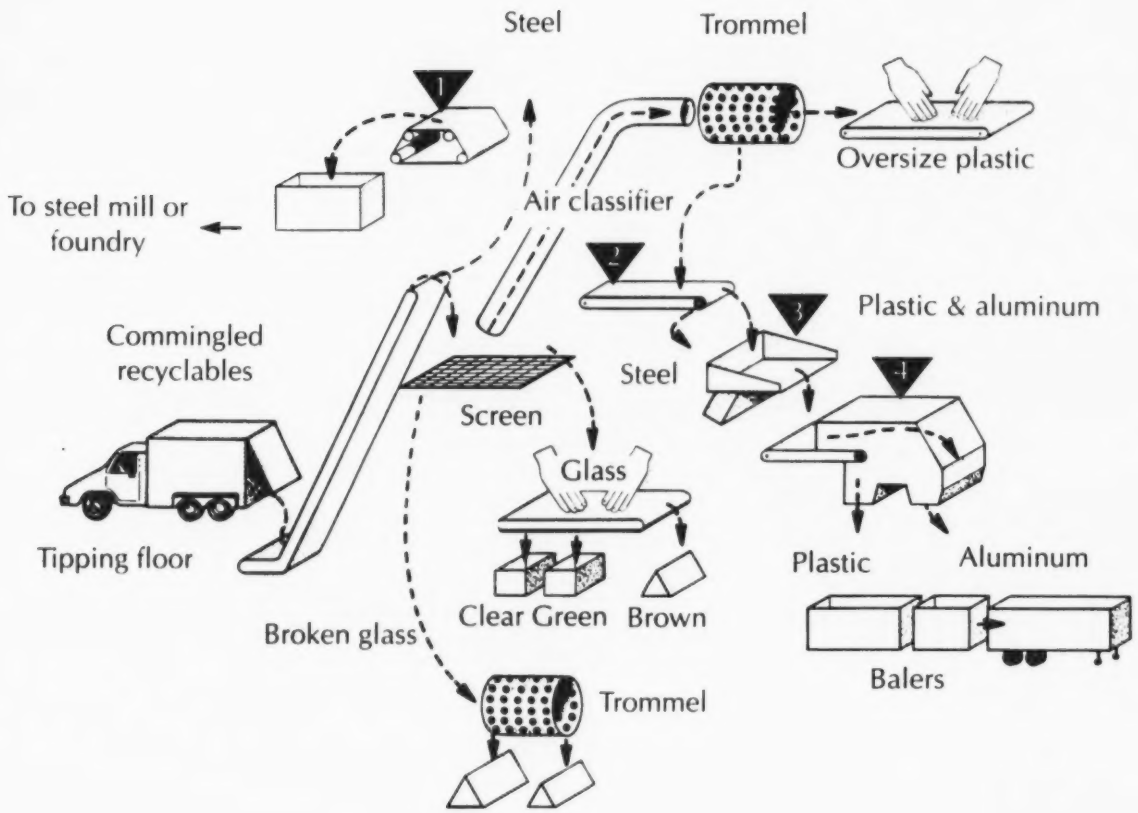
- Create a concept map using the terms: visible light, color, electromagnetic waves, rods, cones, human eye.


Visible Light
is a type of
Electromagnetic Wave
perceived as Color by the Cones
perceived as black & white by the Rods
which are part of the
Human Eye

- Rank in order of increasing temperature: blue flame, red flame, white flame, yellow flame. Explain in terms of wavelengths of emitted light.

red flame — lowest temperature, longest wavelength
↓
yellow flame
↓
white flame
↓
blue flame — highest temperature, shortest wavelength

Example of Processing Recyclables at a Materials Recovery Facility

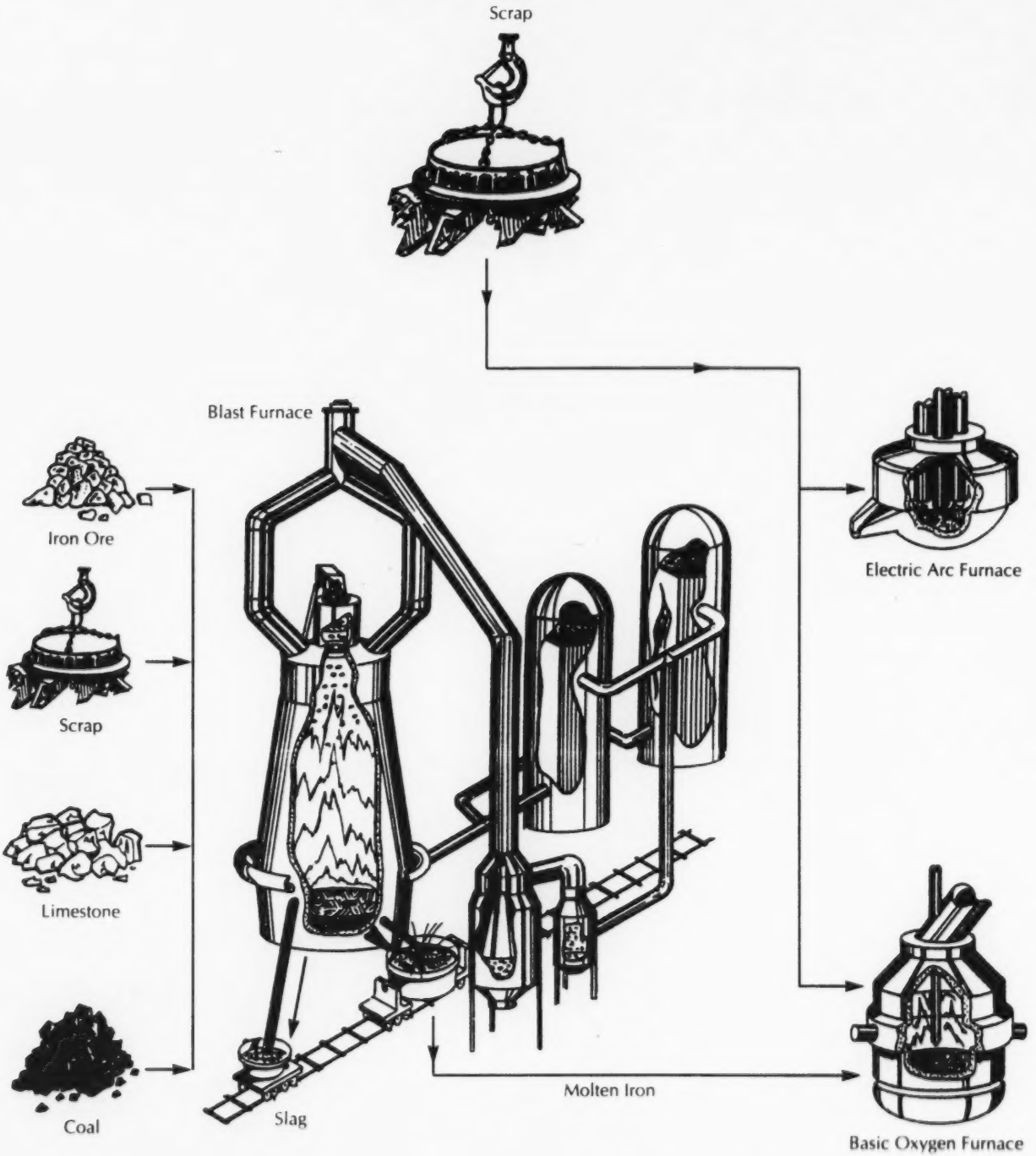


Equipment List

1. Belt Magnet
2. Magnetic Pulley
3. Vibratory Feeder
4. Nonferrous Metal Separator

Source: *Eriez Magnetics, Erie, PA.*

The Making of Steel



Lesson: Sort & Produce

HAVE YOU EVER WONDERED?

How recyclable material is sorted and processed for recycling into new products?

Collecting recyclable materials and setting them at the curb or taking them to a drop-off site is only the first step in the recycling process. These materials must somehow find their way to the appropriate manufacturing facility to be made into new products before recycling is complete. Often recyclable materials are commingled (mixed together) and must be sorted at a Materials Recovery Facility (MRF, pronounced *murf)* before they can be baled and shipped to a manufacturer.

Picking up, sorting, shipping and recycling materials requires work from both humans and machinery. Humans use muscles and bones to do work, but there is a limit to the amount of work that muscles and bones can do. Machines have been invented to help increase work capacity, allowing humans to accomplish tasks that muscles and bones alone cannot do. At a MRF, some of the sorting is done by hand, but machines such as forklifts, conveyor belts and balers are often used to get the job done. Machinery is used to transport the baled and sorted recyclables to the manufacturing plant where they will be made into new products. Machines are also critical to manufacturing processes.

The Lever: A Simple Machine

All machinery, no matter how complicated, is made from a combination of simple machines, of which there are only six: the lever, the inclined plane, the screw, the wheel and axle, the wedge, and the pulley. Perhaps the simplest of all machines is the lever, a rigid bar to which a force is applied to lift an object. All levers have three parts: a fulcrum, a resistance arm and an effort arm. The fulcrum is the pivot point. The resistance arm extends from the fulcrum to the resistance, or the mass being lifted. The effort arm extends from the fulcrum to the effort, or the point where the force is applied.

Your bones and muscles are levers, as shown in *Musculoskeletal Levers*, page 43. The assembly of muscle, bone and joint forms a lever: the bone is the rigid bar, the joint is the fulcrum, and the muscle supplies the force. When the muscle contracts it pulls on the bone, causing the bone to pivot about the joint.

Whether musculoskeletal or mechanical, levers can be classified three ways, based on the relative locations of the arms and the fulcrum. Refer to *Classes of Levers*, page 44.

- Class 1. The fulcrum is located between the effort and resistance arms.
- Class 2. The fulcrum is on one end, with the effort applied at the other end and the resistance in between.
- Class 3. The fulcrum is on one end, with the resistance on the other end and the effort applied in between.

Class 1 and 2 levers effectively overcome large resistances with relatively little effort. Class 3 levers actually require a large amount of effort to overcome the resistance, but have the benefit of speed. Closing a door by pushing near the hinges (a Class 3 lever) requires a good deal of force, but the outer edge of the door rapidly moves a large distance.

Scrap Steel to New Steel

Steel contains a high proportion of iron with small amounts of carbon and other elements. Recycling an empty paint or food can reduces the need to make steel from iron ore. This allows a significant savings in natural resources and energy because making steel from iron ore requires the following steps:

1) Mine the ore from the earth;
2) Beneficiate the ore to sort it out from sand and rock;

3) Reduce the ore in a blast furnace to separate the iron from most impurities;

4) Combine the iron with recycled steel and add desired elements in appropriate proportions;

5) Cast molten steel into molds, sheets or slabs and move through a series of shaping, heating and cooling processes to produce a variety of sizes, shapes and types of solid steel.

Steel can also be made completely from scrap steel without adding molten iron.

Colors in a Steel Mill

Although cold steel generally is gray in color, when you think of steel in a steel mill, you might envision glowing reds, oranges, yellows and the hot white of molten steel. Steel is made at very high temperatures, which produce the array of colors seen. Iron melts at 1535 degrees Celsius. The temperatures of some familiar objects are given below:

Material	Temperature
dry ice (frozen $C0_2$)	-20°C
melting ice	0°C
human body	37°C
boiling water	100°C
red-hot iron	500-650°C
white-hot (molten) iron	1535°C
filament in 100-W bulb	2200-2700°C
surface of the sun	5000-6000°C

Source: *SciencePlus: Technology and Society*

The colors that we see are a result of electromagnetic waves emitted through space. Electromagnetic waves are a form of energy, and can be simulated by shaking a jump rope up and down. When the rope is shaken slowly, the waves move slowly and the centers of the waves are far apart. The frequency is low and the wavelength is high. When the rope is shaken rapidly, the waves move rapidly and the centers are close together. The frequency is high and the wavelength is low. Most electromagnetic waves cannot be detected by the human eye because the wavelength is either too long or too short, and not within the range of the human eye. However, the human eye can detect a specific range of wavelengths known as visible light.

Light enters the eye through the cornea (the transparent cover of the eye) passes through the pupil and the lens and strikes the retina, the layer at the back of the eye. The retina contains photoreceptors that act like tiny antennae when responding to incoming light. There are two types of photoreceptors: the rods and the cones, each shaped as their names imply. Rods are very sensitive to light and function in black-and-white vision at night. Rods predominate toward the periphery of the retina. Cones are less sensitive to light than rods, but are responsible for color vision. Cones are more concentrated in the center of the retina, in an area called the fovea. (Refer to *The Human Eye*, page 49.)

Light is composed of one or more colors, each of which has a specific wavelength (and frequency). Different cones in the eye are sensitive to different wavelengths. When red light enters the eye, it stimulates the cones sensitive to long wave light, and we see red. Yellow light entering the eye stimulates cones sensitive to intermediate wave lengths, and we see yellow. Blue light stimulates cones sensitive to short wave light, and we see blue. Since light may be composed of several wavelengths together, different types of cones can be stimulated at the same time, allowing us to distinguish a continuum of colors. White light, which contains all wavelengths of visible light in equal proportions, stimulates long, intermediate and short wave cones in equal proportions.

We see light in one of two ways, either as waves emitted from their source, or as waves reflected off other objects. A room-temperature object, such as a bar of steel, emits electromagnetic waves, but at wavelengths so long that we cannot see them. The gray color that we see is a result of light reflected off the steel. As an object is heated, it begins to emit shorter waves. At a temperature of about 600 degrees Celsius, an object begins to emit the longest waves that we can see, red light. As the temperature rises, more of the shorter waves are emitted by the object, and the light appears yellow. At 1200 degrees all the different waves to which the eye is sensitive are emitted and we see the object as "white hot."

Activity 5: Bones and Levers

Objectives

The learner will compare and contrast levers in the human body with levers in machinery, by:

- recognizing and utilizing lever classification systems for exploring musculoskeletal and mechanical levers
- formulating hypotheses to explain the interaction of components of levers
- refining the use of mathematics skills by applying these skills in a scientific investigation
- investigating the working of tools that extend the limits of human capabilities

Time

One or two class periods

Materials/Equipment

Balances or scales (for massing items ranging from a few grams to 5 kilograms)
Cinder blocks (30 x 18 x 18 centimeters)
Nutcrackers (steel)
Paint cans (3.8-liter, with handle, containing some paint and closed tightly)*
Rulers
Steel rods (such as a ring stand rod)
Tape (masking or transparent)
Walnuts (in the shell)

* *This activity may be performed with empty paint cans, but students will perceive greater differences in the levers if there is some paint in the cans to increase the mass.*

Figures/Tables

Musculoskeletal Levers, page 43

Classes of Levers, page 44

Procedure

1. Use the *Background: Student*, pages 39 and 40, to introduce levers and their uses. Copy onto transparencies or use as handouts the figures *Musculoskeletal Levers* and *Classes of Levers*. Explain that muscles and bones form a system of levers in the human body. Describe the three classes of levers, indicating for each type of lever the position of the fulcrum in relation to the effort and resistance arms. Draw special attention to the effort arm in a Class 2 lever, and the resistance arm in a Class 3 lever.

2. Divide the students into lab groups. Provide each group with a balance or scale, cinder block, nutcracker, paint can, ruler, steel rod, tape, and two walnuts.

3. Copy and distribute to each student *Activity 5: Student*, pages 45 and 46. Review the steps for testing the different types of levers and lengths of resistance arms. Instruct groups to proceed with the activity.

4. *For further study:*

- Identify other levers in the body. Refer to a biology or anatomy text for illustrations of how muscles are attached to bones. Examine the attachment of muscles and determine the class of levers (e.g., lower leg and hamstrings form a Class 3 lever; forearm and triceps form a Class 1 lever; foot and posterior lower leg muscles form a Class 1 lever.)

- Arrange a tour of a local steel mill or scrap yard to view the process and observe the machinery. Select a piece of equipment and show how its actions simulate actions of the human body. For example, a crane can be compared to the body, with the boom acting like the spine, the cables like the lower back muscles, the pivot like the lower vertebrae, the hook or claw like the human hand.

Collecting and Analyzing Data

1. Assist students in calculating the force for each lever, using the equation:

$$\frac{F}{M} = \frac{R}{E}$$

F = force
M = mass of object
R = length of resistance arm
E = length of effort arm

Remind the students that the equation is easily solved by converting it to:

$$F = \left(\frac{R}{E}\right) M$$

2. Ask students to determine the relationship between force and length of resistance arm for each type of lever. Ask them to compare the perceived effort with the calculated force.

Drawing Conclusions

Q1: *In this activity, what happened to the lengths of the effort arms when you changed the lengths of the resistance arms? Which would require more force to pry the lid off the paint can, a long screwdriver or a short one? Explain. Consider that the length of the resistance arm remains the same while the length of the effort arm changes.*

A1: In this activity, the lengths of the effort arms decreased when the lengths of the resistance arms increased. The shorter effort arms required more force to lift the mass.

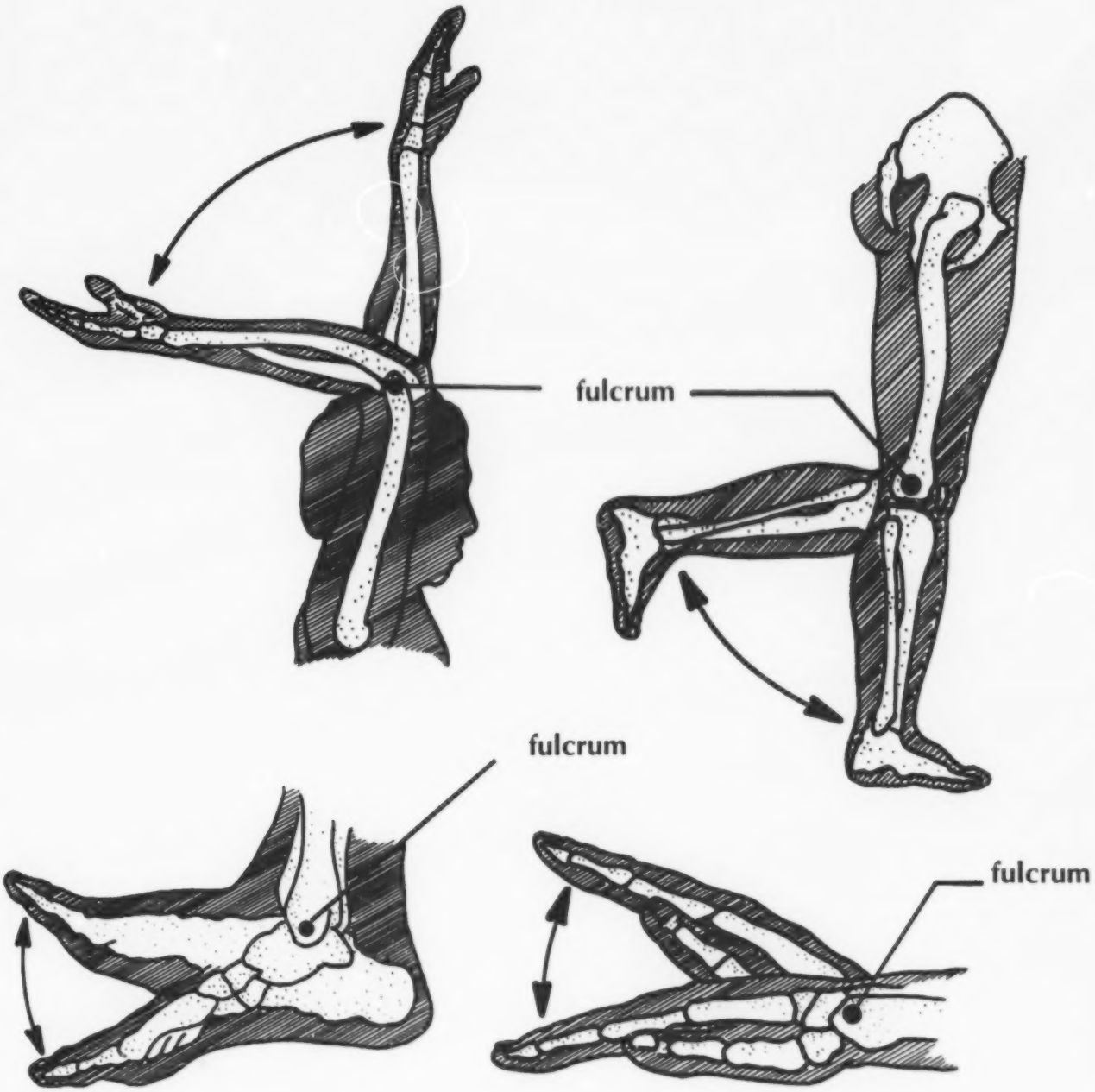
This also applies to lifting the lid from the paint can, even though the length of the resistance arm remains the same while the length of the effort arm changes. The key is the *proportion* between the lengths of the effort arm and resistance arm. A proportionally shorter effort arm will mean more force is required, and vice versa.

Q2: *Nearly 30 million cars throughout the world are recycled every year. Considering that the mass of a typical U.S. passenger car built in 1990 is approximately 1279 kilograms, what type(s) of lever(s) would be found in the machinery at an automobile scrap yard? Why? What advantage would a Class 3 lever have to the human body?*

A2: Class 1 or 2 levers are generally used in machinery because they are more efficient for lifting heavy masses with less force. Class 3 levers require more force to lift a heavy mass, but have greater speed, which could be an advantage for survival. Students can visualize the speed of a Class 3 lever by observing how quickly the hand can be lifted to the shoulder by flexing the biceps muscle (bending the elbow).

Data on car recycling and mass of a passenger car are from: Kiser, Kent, "Total Car Recycling — Just a Green Dream?" *Scrap Processing and Recycling*, September 10, 1992, and S.S. Labana, Ford Motor Company. For more information on car recycling, see the "Collect and Haul" lessons in *Cycles for Science Chemistry* and *Physics*.

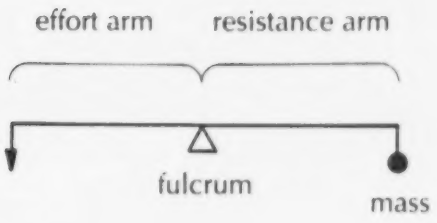
Musculoskeletal Levers

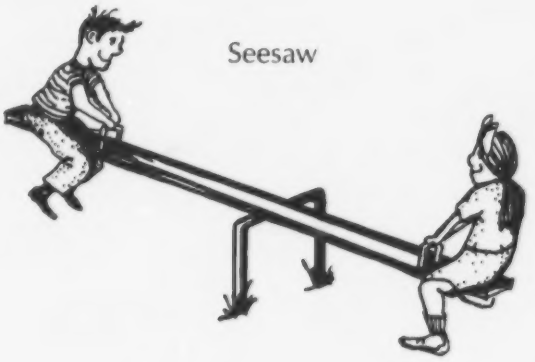


Adapted from: Kreighbaum, Ellen. "Anatomy and Kinesiology." *Aerobic Dance-Exercise Instructor Manual.* San Diego, CA: International Dance-Exercise Association, 1987.

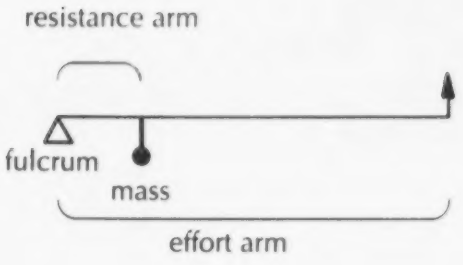
Classes of Levers

Class 1

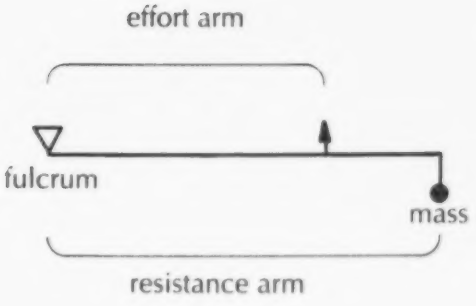


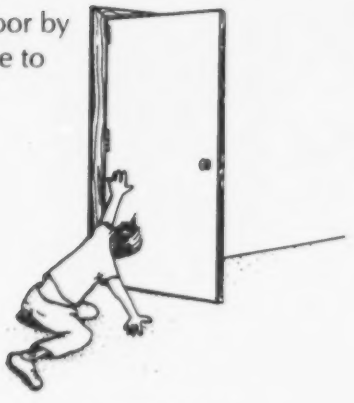


Class 2



Class 3





Adapted from: Naval Personnel, U.S. Bureau of. *Basic Machines and How They Work*. New York, NY: Dover Publications, 1971.

Weiss, Harvey. *Machines and How They Work*. New York, NY: Thomas Y. Crowell Junior Books, 1983.

Activity 5: Bones and Levers

Procedure

1. In this activity you will work with your lab group to test various types of levers, including the bones in your body that operate as levers to make your body move. You will need:

- balance or scale
- 1 cinder block
- 1 nutcracker
- 1 paint can
- 1 ruler
- 1 steel rod
- tape
- 2 walnuts

Safety Tips: Exercise caution when working with the levers. Do not perform Procedure Step 5 if you feel strain in your arm or any other muscle.

2. Classes of levers.

a) Examine the sketch of the steel rod in the figure "Lever Assemblies," page 46. Indicate on the sketch the fulcrum, resistance arm and effort arm of the lever. Refer to the figure *Classes of Levers*, page 44. Is the steel rod a Class 1, 2, or 3 type lever?

b) Repeat a) with the nutcracker.

c) Repeat a) with the forearm. Hint: The bicep muscle is the force that moves the lever. The upper arm is not part of the lever.

3. Steel rod.

a) Mass the paint can and record the mass in the table "Lifting with Levers," page 46.

b) Assemble the lever as shown in the sketch, page 46. Use tape to secure the handle of the can so it does not slip.

c) Adjust the steel rod so the resistance arm is shorter than the effort arm. Measure and record the lengths of the resistance and effort arms.

d) Use the lever to lift the can.

e) Lower the can to the table. Move the steel rod to lengthen the resistance arm. Measure and record the lengths of the arms. Use the lever to lift the can.

f) Place a check mark in the table to indicate which resistance arm (short or long) seemed to require more effort to lift the can.

4. Nutcracker.

a) Mass one of the walnuts and record the mass in the table "Lifting with Levers," page 46.

b) Position the walnut in the nutcracker close to the closed end. Measure the resistance and effort arms and record the lengths in the table.

c) Crack the walnut.

d) Repeat steps a) - c) with the second walnut, positioning the walnut close to the open end of the nutcracker.

e) Place a check mark in the table to indicate which resistance arm (short or long) seemed to require more effort to crack the walnut.

5. Forearm.

a) Record the mass of the paint can in the table "Lifting with Levers," page 46.

b) Position your forearm so it makes a 90 degree angle to your upper arm as shown in the sketch. Hold the handle of the paint can in your hand. Note that this is the long resistance arm. Be sure to enter data in the correct column in the table.

c) Assume that your biceps muscle attaches at four centimeters from your elbow. Working on the outside of your forearm, measure the resistance and effort arms and record the lengths.

d) Use your forearm to lift the can, keeping your elbow and upper arm stationary.

e) Return your forearm to 90 degrees from your upper arm. Repeat steps a) - d), with the can on your forearm to shorten the resistance arm.

f) Place a check mark in the table to indicate which resistance arm (short or long) seemed to require more effort to lift the can.

Collecting and Analyzing Data

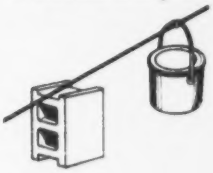
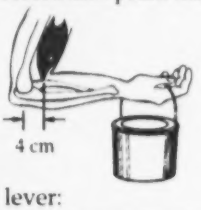
1. Calculate the force for each test using the equation:

$$\frac{F}{M} = \frac{R}{E}$$

F = force
M = mass of object
R = length of resistance arm
E = length of effort arm

2. Determine the relationship between force and length of resistance arm. Compare perceived effort with the calculated force in each test.

Lever Assemblies

Steel rod and paint can	Nutcracker and nut	Forearm and paint can
		
Class of lever:	Class of lever:	Class of lever:

Lifting with Levers

Resistance arm	Mass of object to be moved, g (M)	Length of arm, cm		Perceived effort *(place a check by the resistance arm, short or long, that seemed to require more force)*	Force (F) $\frac{F}{M} = \frac{R}{E}$
		Resistance (R)	Effort (E)		
Steel rod					
short					
long					
Nutcracker					
short					
long					
Forearm					
short					
long					

Drawing Conclusions

1. In this activity, what happened to the lengths of the effort arms when you changed the lengths of the resistance arms? Which would require less force to pry the lid off the paint can, a long screwdriver or a short one? Explain.

2. Nearly 30 million cars throughout the world are recycled every year. Considering that the mass of a typical U.S. passenger car built in 1990 is approximately 1279 kilograms, what type(s) of lever(s) would be found in the machinery at an automobile scrap yard? Why? What advantage would a Class 3 lever have to the human body?

Activity 6: The Color of Hot Metals

Objectives

The learner will conduct an investigation on the relationships among heat, wavelengths of visible light, and color, by:

- utilizing the chart of wavelengths of visible light to predict temperatures of flames and explain color changes as metals are heated
- formulating a description of the impact of electromagnetic waves on perception of color
- refining the use and understanding of the concepts of mass and specific heat
- comparing school-based science perspectives with technological applications

Time

One class period to perform the activity

One additional class period if students are to design and perform a new experiment

Safety Tips

Review safe and proper use of the Bunsen burner and candles. Remind students to avoid touching hot metals with their bare hands. Students should wear goggles for this activity.

Materials/Equipment

Balances
Beakers (250-mL)
Bunsen burners
Candles
Forceps
Matches
Thermometers
Washers (aluminum)
Washers (copper)
Washers (steel)

Optional: Color chart of the continuous spectrum of visible light

Figures/Tables

The Human Eye, page 49
Wavelengths of Visible Light, page 50

Procedure

1. Copy onto transparencies or use as handouts the figures *The Human Eye* and *Wavelengths of Visible Light*. Display a color chart of the spectrum of visible light if one is available. Use the figures and the *Background: Student*, pages 39 and 40, to discuss the anatomy of the human eye and how different wavelengths of visible light are distinguished as color. Point out the narrow range of waves that can be seen by the human eye. Explain that frequency and wavelength can be used to characterize any wave, but frequency is generally used for radio waves, while wavelength is generally used for light waves.

   Describe how shorter wavelengths are emitted as the temperature rises. Refer to standard biology, chemistry and physics texts for more information on the human eye, light and color.

2. Divide the class into lab groups. Provide each group with a balance, 250-mL beaker, a Bunsen burner, a candle, matches, a thermometer, an aluminum washer, copper washer and steel washer.

3. Copy and distribute to each student *Activity 6: Student*, pages 51 and 52. Review the steps for testing the temperature of the flames and observing colors of flames and hot metals. Instruct lab groups to proceed with the activity.

4. *For further study:*

- Present this scenario to the class: Sunlight strikes the chlorophyll pigment of a healthy leaf. No one is there to see the leaf (that is, no creature with eyes that have color-receptive cones). Ask the questions: What wavelength is reflected by the leaf? (5.3×10^{-7}, which appears green to the eye.) If no one is there to see the leaf, does it have a color? (This question is a brain-teaser. The wavelength of light reflected by the leaf is

within the range of visible light, so it can be argued that the leaf has color regardless of who or what is there to see it. However, it can also be argued that since the reflected light must strike the cone of an eye before it can be translated into color, the color does not exist unless an eye is there to see it.)

Collecting and Analyzing Data

1. Assist groups in calculating the temperature of the flames. Explain that this can be done by assuming that the heat lost by the metal equals the heat gained by the water, so that:

   mass of metal x specific heat x temperature change of metal = mass of water x temperature change of water.

   In addition,

   temperature change of the metal = flame temperature - final water temperature

   and

   temperature change of the water = final water temperature - initial water temperature.

   If

   T = temperature of the flame
   A = mass of the steel washer
   B = mass of the water
   C = initial water temperature
   D = final water temperature
   470 = specific heat of iron (steel contains a high percentage of iron)

   then

   $A \times 470 \times (T - D) = B \times (D - C)$

   Solving for T, this becomes:

   $$T = \left(\frac{B(D-C)}{470A}\right) + D$$

   Ask students to compare the observed flame temperatures with their predictions.

   For more information on specific heat, refer to a chemistry or physics text.

2. Refer students to Procedure Step 3. When repeating the experiment using the candle, was it necessary to start with water of the same initial temperature? Instruct groups to design and write instructions to an experiment to test their hypotheses. Encourage them to do the same for other questions that arose during the activity. If time permits, allow groups to perform the experiments. (It is not necessary to start with the same initial water temperature each time the experiment is performed.)

Drawing Conclusions

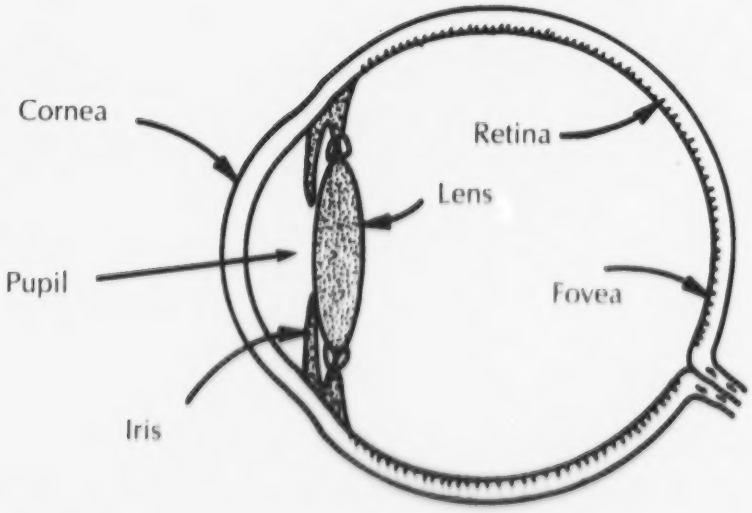
Q1: *In a steel mill you would find gray machinery, red hot ingots (bars) of steel, yellow sparks and white hot molten steel. Explain what you would see in terms of temperature, electromagnetic waves, and cones in the human eye.*

A1: The gray machinery is not emitting visible light of its own, but is reflecting gray light from other sources. As the steel is heated, it begins to emit long wave visible light that is picked up by long wave cones in the eye, and perceived as red. As the steel becomes even hotter, it emits shorter wave yellow light that stimulates more of the intermediate wave cones in the eye. At melting temperature, the steel emits white light that stimulates long, intermediate, and short wave cones. The same sequence applies to the heating and melting of other metals.

Q2: *Which is hottest, a red star, a white star such as Earth's sun, or a blue star? Explain.*

A2: A blue star is hottest; it is emitting predominately short waves of visible light. A red star is coolest; it is emitting predominately long waves visible light. A white star such as Earth's sun is intermediate in temperature; it emits all wavelengths of light, including the intermediate ranges.

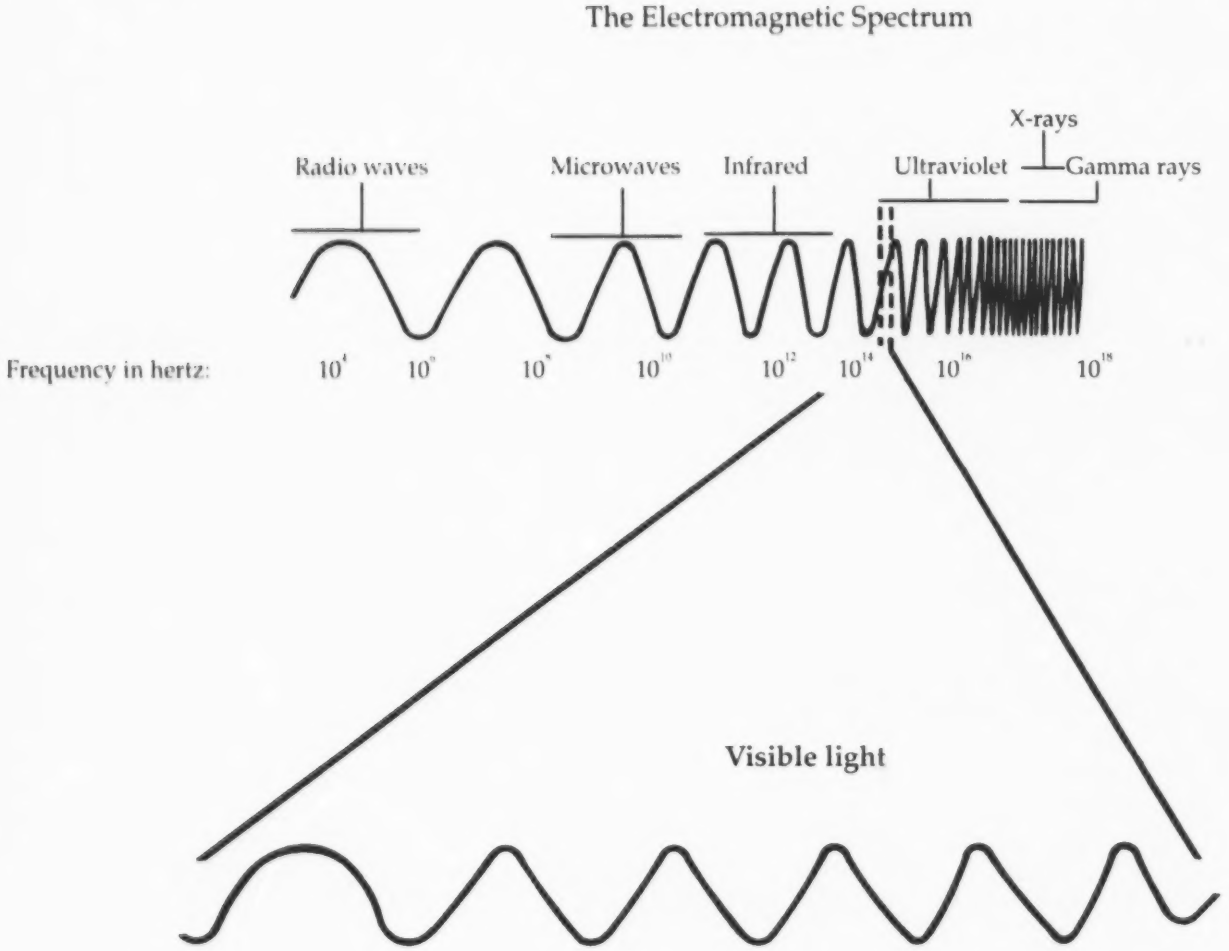
The Human Eye



Highly magnified view of rods and cones in the human eye

Source: Hewitt, Paul G. *Conceptual Physics*. 6th ed. San Francisco, CA: HarperCollins Publishers, 1989.

Wavelengths of Visible Light



Wavelength in meters:	Red	Orange	Yellow	Green	Blue	Violet
	7.0×10^{-7}	6.0×10^{-7}	5.8×10^{-7}	5.3×10^{-7}	4.7×10^{-7}	4.0×10^{-7}
Frequency in hertz:	4.3×10^{14}					7.5×10^{14}

1 hertz = 1 wave per second

Adapted from: Hewitt, Paul G. *Conceptual Physics*. 6th ed. San Francisco, CA: HarperCollins Publishers, 1989.

Activity 6: The Color of Hot Metals

Procedure

1. In this activity, you will be working in lab groups to observe how a material changes color as it becomes hotter. You will need:

- 1 balance
- 1 beaker (250-mL)
- 1 Bunsen burner
- 1 candle
- 1 pair of forceps
- matches
- 1 thermometer
- 1 washer (aluminum)
- 1 washer (copper)
- 1 washer (steel)

Safety Tips: Exercise caution to avoid burns when working with candles or Bunsen burners. Do not touch hot metals with your bare hands. Wear goggles for this activity.

2. Observe the color of each flame.

a) Light the Bunsen burner and the candle. Observe and record the color(s) of the flames in the chart "Flame Color," page 52.

b) Predict the temperature of each flame. Record your prediction in the chart.

c) Turn off the Bunsen burner and blow out the candle.

3. Observe color changes in the steel washer and measure the temperature of the flames.

a) Mass the steel washer. Record the mass in the table "Flame Temperature," page 52.

b) Observe the color of the steel washer. Record the color in the chart "Color Changes in Hot Metals," page 52.

c) Add 100 mLs of water to the beaker. Measure and record the initial temperature of the water.

d) Light the Bunsen burner. Use the forceps to hold the washer in the flame for one minute. Observe the color of the washer as it is held in the flame. Record your observations in the chart "Color Changes in Hot Metals," page 52.

e) After one minute, remove the washer from the flame and quickly place it in the beaker of water. Turn off the Bunsen burner.

f) Insert the thermometer into the beaker of water, but do not allow it to touch the washer. Stir the water gently and observe what happens to the temperature. When the temperature has stabilized, record the final temperature in the chart "Color Changes in Hot Metals."

g) Retrieve the washer from the water and dry it with a paper towel.

h) Light the candle. Repeat steps c)-g) using the candle in place of the Bunsen burner.

4. Observe color changes in aluminum and copper.

a) Observe the colors of the aluminum and copper washers and record them in the chart "Color Changes in Hot Metals."

b) Repeat Procedure, Step 3d) using the aluminum washer in place of the steel washer.

c) Repeat Procedure, Step 3d), using the copper washer.

5. Refer to *Wavelengths of Visible Light*, page 50. Record the wavelengths of the observed colors in the charts "Flame Color" and "Color Changes in Hot Metals."

Collecting and Analyzing Data

1. Calculate the temperature of the flames using the following formula:

$$T = \left(\frac{B(D-C)}{470A}\right) + D$$

T = temperature of the flame
A = mass of the steel washer
B = mass of the water
C = initial water temperature
D = final water temperature
470 = specific heat of iron

2. Refer to Procedure Step 3. When repeating the experiment using the candle, was it necessary to start with water of the same initial temperature? On a separate sheet of paper, design and write the instructions for an experiment to test your hypothesis. Do the same for other questions that arose during the activity. If time permits, perform the new experiment.

Flame Color

Flame	Color(s)		Predicted flame temperature, °C
	Observed	Wavelength, m	
Candle			
Bunsen burner			

Flame Temperature

Mass of steel washer, g (A)		Mass of water, g (1mL of water = 1g) (B)	
Flame	Water Temperature, °C		Predicted flame temperature, °C (T) $T = \left(\frac{B(D-C)}{470A}\right) + D$
	Initial (C)	Final (D)	
Candle			
Bunsen burner			

Color Changes in Hot Metals

Metal	Initial Color	Color(s) when heated
Steel	*Color:* *Wavelength:* $> 7 \times 10^{-7}$ *m*	*Color:* *Wavelength:*
Aluminum	*Color:* *Wavelength:* $> 7 \times 10^{-7}$ *m*	*Color:* *Wavelength:*
Copper	*Color:* *Wavelength:* $> 7 \times 10^{-7}$ *m*	*Color:* *Wavelength:*

Drawing Conclusions

1. In a steel mill you would find gray machinery, red hot ingots (bars) of steel, yellow sparks and white hot molten steel. Explain what you would see in terms of temperature, electromagnetic waves and cones in the human eye.
2. Which is hottest: a red star, a white star (such as Earth's sun), or a blue star? Explain.

Glossary

anaerobic without the presence of oxygen.

blanching a short heat treatment in the processing of some fruits and vegetables to inactivate naturally occurring enzymes and kill some microorganisms.

brine a seven to ten percent salt solution added to some processed foods to reduce bacterial spore resistance to thermal processing.

composting the decomposition of organic wastes under aerobic conditions; the resulting product may be added to soil to improve soil properties.

cone the portion of the human eye responsible for distinguishing color.

durables products generally having a lifetime of three years or more, such as major appliances, small appliances, electronics, furniture, rubber tires, and lead acid automobile batteries. Non durables are products having a lifetime of less than three years, such as paper, plastic plates, other disposable food service products, disposable diapers, clothing, and footwear.

effort arm the part of the rigid bar of a lever to which force is applied; extends from the fulcrum to the point of force.

electromagnetic wave a wave made by resonating electric and magnetic fields. A wave is a vibration which allows energy to move from one place to another.

food processing any process performed on food which takes the food past the raw stage. Includes canning, freezing, and drying.

fulcrum the pivot point of a lever.

integrated solid waste management a policy of waste management which involves examining all the available options and selecting the combination of methods which is most effective for that particular situation; options can include source reduction, recycling, composting, waste-to-energy and landfilling.

leachate water which has trickled down through a landfill and contains dissolved materials, some of which may be toxic.

macroinvertebrate an organism without a backbone and large enough to see without the aid of a microscope.

methane a colorless, odorless, flammable gas. Methane is a hydrocarbon which makes up a large part of natural gas. It is formed when decomposition occurs in anaerobic conditions.

municipal solid waste trash or garbage from household, commercial, institutional, and light industrial sources which normally is managed by local government agencies.

organic waste discarded materials, such as kitchen scraps, yard clippings, paper or cardboard, which originally came from a living thing.

resistance arm the part of the rigid bar of a lever which supports the mass being lifted; extends from the fulcrum to the mass.

rod the portion of the human eye which detects light but not color; objects seen by the rods appear in black-and-white.

sanitary landfill a carefully engineered site for the safe disposal of solid waste, equipped with leachate collection systems and methane gas controls.

shelf life the period of time during which a material may be stored and remain suitable for use.

thermal processing steam or boiling water treatment performed on sealed cans or jars of food to kill food spoilage microorganisms and spores.

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Did You Know? Steel Recycling

- For each ton of steel recycled, 2500 pounds of iron ore, 1000 pounds of coal, and 40 pounds of limestone are saved.

- Through all of its recycling efforts, the steel industry saves an average of 600 trillion Btu's each year, the energy equivalent to electrically power more than 18 million households for a year.

- More than 90 percent of all food cans are made of steel, four percent of all beverage cans, and most of the paint and aerosol cans.

- Steel products, such as cars, cans and appliances, contain about 25 percent recycled steel; heavy products, such as structural beams and plates used in construction, contain virtually 100 percent recycled steel.

- Already, more than 66 percent of all steel in the U.S. is recycled into new products. Cars, appliances, machinery, and even demolished buildings provide a constant supply of steel scrap that is used to produce new steel.

- Steel is used in construction to build factories, stores, office buildings, and transportation systems. This dependable, durable, affordable material is the heart of the American way of life.

- Consumers have relied on the steel can for the preservation of fruits and vegetables, longer shelf life and tamper resistance. Often called "tin" cans, steel cans come in approximately 600 sizes, shapes and styles, containing over 2,500 different products.

- For decades, bridge builders have selected steel to expand the world's ground transportation systems. Over the years, new, higher strength steels have been developed, including those with chemical properties that inhibit corrosion and deterioration.

- Steel, because of its structural uses, is often unseen. Steel nails, screws, and bolts hold together our homes, schools and offices, and have for generation after generation.

- Steel is now used for framing houses as well as providing the structure for commercial buildings.

- Today's automobiles offer many steel applications: corrosion-resistant coated sheet steels in body panel configurations, and steel bars used in axles, gears, bearings, drive trains, engine parts, and steering and suspension assemblies. Steel wire also forms integral parts of the whole car as it serves to operate and control the vehicle. Steel tubing helps to reduce weight and to cut production costs.

- During the 19th century, iron and steel made possible the development of the American transcontinental railroad system. Steel formed our nation's arteries — it carried railroads across the nation and roads across the rivers. The "iron horse" of yesterday was known for its speed and reliability. Today's modern rail transportation maintains that reputation in a faster-paced world. And steel continues to be the material of choice for building the systems that link people and products across the country.

- One hundred years ago, steel in construction made possible the first skyscrapers to be built. Continuing advances in architectural design and steel technology make it possible to use less steel to build larger, taller, stronger, and more flexible structures.

Resources

Contact the following organizations for information on recycling and other materials.

Aluminum Recycling Association
1000 16th Street, NW, Suite 400
Washington, DC 20036
202/785-0550

American Forest and Paper Association
1250 Connecticut Avenue, NW, Suite 200
Washington, DC 20036
202/463-2420

American Iron and Steel Institute
1101 17th Street, NW, Suite 1300
Washington, DC 20036
202/452-7100

American Plastics Council
1275 K Street, NW, Suite 500
Washington, DC 20005
202/371-5319

Aseptic Packaging Council
1000 Potomac Street, NW, Suite 401
Washington, DC 20007
202/333-5900

Association of Home Appliance Manufacturers
20 N. Wacker Dr.
Chicago, IL 60606
312/984-5800

Can Manufacturers Institute
1625 Massachusetts Avenue, NW
Washington, DC 20036
202/232-4677

Earth Kind
2100 L Street, NW
Washington, DC 20037
202/778-6149

Glass Packaging Institute
1627 K Street, NW, Suite 800
Washington, DC 20006
202/887-4850

Institute of Scrap Recycling Industries
1325 G Street, NW
Washington, DC 20005
202/466-4050

Keep America Beautiful, Inc.
Mill River Plaza, 9 West Broad Street
Stamford, CT 06902
203/323-8987

National Aeronautic and Space Administration
Johnson Space Center
Attn: AP-3
Houston, TX 77058
713/483-5111

National Recycling Coalition, Inc.
1101 30th Street, NW, Suite 305
Washington, DC 20007
202/625-6406

National Wildlife Federation
1412 16th Street, NW
Washington, DC 20036
202/797-6800

Steel Recycling Institute
680 Andersen Drive
Pittsburgh, PA 15220-2700
412/922-2772

Steel Shipping Container Institute
1101 14th St., NW, Suite 1020
Washington, DC 20005
202/408-1900

U.S. Department of Agriculture
Human Nutrition Information Service
6505 Belcrest Rd
Hyattsville, MD 20782

Teacher Evaluation

Please return evaluation form to:

Cycles for Science/Biology
Steel Recycling Institute
680 Andersen Drive
Pittsburgh, PA 15220-2700
412/922-2772

Name _____ School/Company _____

Address _____ Phone ( ) _____

City _____ State _____ Zip _____

Subject area(s) taught _____

Grade level(s) taught _____ Number of students _____

In future editions of *Cycles for Science/Biology*, we plan to include the average time in minutes for each activity. In the box below, please record the number of minutes it took for your class to complete each activity.

	Minutes		Minutes		Minutes
Reducing Food Spoilage and Waste	_____	Leachate Collection	_____	Bones and Levers	_____
Space Food	_____	Composting with Worms	_____	The Color of Hot Metals	_____

We value your comments on the ***Cycles for Science*** curriculum supplement. Please enclose a copy of any or all of the lessons with your comments and changes marked in red. If you have added curriculum or teaching aids, please enclose photocopies with an explanation.

Make further comments on a separate page.

If we use your comments or ideas to improve the curriculum supplement, you will be credited in the acknowledgements of the 2nd edition of ***Cycles for Science/Biology***.